

The CANADIAN FIELD-NATURALIST

A JOURNAL OF FIELD BIOLOGY AND ECOLOGY



Volume 131, Number 1

January–March 2017

Published by THE OTTAWA FIELD-NATURALISTS' CLUB, Ottawa, Canada

The Ottawa Field-Naturalists' Club

FOUNDED IN 1879

Patron

His Excellency the Right Honourable David Johnston, C.C., C.M.M., C.O.M., C.M.
Governor General of Canada

The objectives of this Club shall be to promote the appreciation, preservation and conservation of Canada's natural heritage; to encourage investigation and publish the results of research in all fields of natural history and to diffuse information on these fields as widely as possible; to support and cooperate with organizations engaged in preserving, maintaining or restoring environments of high quality for living things.

Honorary Members

Ronald E. Bedford	Francis R. Cook	C. Stuart Houston	E. Franklin Pope
Charles D. Bird	Bruce Di Labio	Ross A. Layberry	Allan H. Reddoch
Fenja Brodo	Anthony J. Erskine	Robert E. Lee	Joyce M. Reddoch
Irwin M. Brodo	J. Bruce Falls	John McNeill	Dan Strickland
Daniel F. Brunton	Peter W. Hall	Theodore Mosquin	John B. Theberge
Michael D. Cadman	Christine Hanrahan	Robert W. Nero	Sheila Thomson
Paul M. Catling			

2017 Board of Directors

President: Diane Lepage	Annie Bélair	Diane Kitching	Jeffery M. Saarela
1st Vice-President: Jakob Mueller	Fenja Brodo	Dwayne Lepitzki	Henry Steger
Recording Secretary: Lynn Ovenden	Owen Clarkin	Rémy Poulin	Eleanor Zurbrigg
Treasurer: Ann MacKenzie	Edward Farnworth	Gordon Robertson	

To communicate with the Club, address postal correspondence to: The Ottawa Field-Naturalists' Club, P.O. Box 35069, Westgate P.O., Ottawa, ON, K1Z 1A2, or e-mail: ofnc@ofnc.ca. For information on Club activities, go to www.ofnc.ca

The Canadian Field-Naturalist

The *Canadian Field-Naturalist* is published quarterly by The Ottawa Field-Naturalists' Club. Opinions and ideas expressed in this journal do not necessarily reflect those of The Ottawa Field-Naturalists' Club or any other agency.

Website: www.canadianfieldnaturalist.ca/index.php/cfn

Editor-in-Chief: Dr. Dwayne Lepitzki

Copy Editors: Sandra Garland and Dr. John Wilmshurst

Book Review Editor: Barry Cottam

Subscription Manager: Eleanor Zurbrigg: subscriptions@canadianfieldnaturalist.ca or via postal address above.

Assistant Editor: Dr. Amanda Martin

Typographer: Wendy Cotie

Webmaster: Dr. Bill Halliday

Associate Editors:	Dr. Ron Brooks	Dr. Jennifer R. Foote	Jon McCracken	Dr. Jeffery M. Saarela
	Dr. Carolyn Callaghan	Dr. Graham Forbes	Dr. Garth Mowat	David C. Seburn
	Dr. Paul M. Catling	Thomas S. Jung	David Nagorsen	Dr. Jeffrey H. Skevington
	Dr. François Champleau	Dr. Donald F. McAlpine	Dr. Marty Obbard	

Chair, Publications Committee: Dr. Jeffery M. Saarela

All manuscripts intended for publication except Book Reviews can be addressed to the Editor and sent by e-mail: editor@canadianfieldnaturalist.ca **or postal mail (with disk):** P.O. Box 1979, Banff, AB T1L 1B7; (403) 762-0864. Online submissions through the website are encouraged.

Book-review correspondence should be sent to the Book Review Editor by e-mail: b.cottam@rogers.com **or postal mail:** 98 Norman Street, Ottawa, ON K1S 3K6

Subscriptions and Membership:

Subscription rates for individuals are \$40 (online only), \$50 (print only), or \$60 (print + online). Libraries and other institutions may subscribe for \$60 (online only or print only) or \$90 (print + online). All foreign print subscribers and members (including USA) must add \$10 to cover postage. The Ottawa Field-Naturalists' Club annual membership fee of \$40 (individual), \$45 (family), or \$20 (student) includes an online subscription to *The Canadian Field-Naturalist*. Members can receive printed issues of CFN for an additional \$30 per volume (four issues). For further details, see <http://ofnc.ca/member.php>. The club's regional journal, *Trail & Landscape*, covers the Ottawa District and regional Club events and field trips. It is mailed to Ottawa area members, and is available to those outside Ottawa on request. It is available to libraries at \$33 per year. Subscriptions, applications for membership, notices of changes of address, and undeliverable copies should be sent to subscriptions@canadianfieldnaturalist.ca or mailed to: The Ottawa Field-Naturalists' Club, P.O. Box 35069, Westgate P.O., Ottawa, ON, K1Z 1A2 Canada. Canada Post Publications Mail Agreement number 40012317. Return postage guaranteed.

The Thomas H. Manning fund, a special fund of the OFNC, established in 2000 from the bequest of northern biologist Thomas H. Manning (1911–1998), provides financial assistance for the publication of papers in the CFN by independent (non-institutional) authors, with particular priority given to those addressing arctic and boreal issues. Qualifying authors should make their application for assistance from the Fund at the time of their initial submission.

COVER: The Ramsay Prairie of the Burnt Lands Alvar in Lanark County, Ontario is dominated by provincially rare Northern Dropseed grass (*Sporobolus heterolepis* A. Gray) and supports a wide variety of characteristic alvar flora and fauna. This 65 ha meadow is a little-changed relict landscape from postglacial times 9000–10 000 years B.P. and represents the easternmost naturally occurring prairie in Canada. See the Thematic Collection in this issue by Daniel Brunton and Paul Catling, pages 75–79. Photo: Daniel F. Brunton, 4 August 2015.

The CANADIAN FIELD-NATURALIST

A JOURNAL OF FIELD BIOLOGY AND ECOLOGY

Volume 131

2017

MCZ
LIBRARY
SEP 15 2017
HARVARD
UNIVERSITY

Promoting the study and conservation
of northern biodiversity since 1880

THE OTTAWA FIELD-NATURALISTS' CLUB

OTTAWA

CANADA

Publication Trends in *The Canadian Field-Naturalist*, 1980–2015

WILLIAM D. HALLIDAY

Department of Biology, University of Victoria, 3800 Finnerty Road, Victoria, British Columbia V8P 5C2 Canada; email: wdhalliday@gmail.com

Halliday, William D. 2017. Publication trends in *The Canadian Field-Naturalist*, 1980–2015. *Canadian Field-Naturalist* 131(1): 1–9. <https://doi.org/10.22621/cfn.v131i1.1949>

I examined publication trends for *The Canadian Field-Naturalist* (CFN) between 1980 and 2015 to determine whether a general decrease in natural history studies has been affecting CFN. I also establish a baseline of the types of authors that publish in CFN, and the types of studies that are typically published. Fewer but longer articles are being published every year. More authors per article with greater collaboration are publishing every year. The majority of authors are Canadian, but a large number of authors are from the USA. The majority of studies focus on vertebrates, and most of these focus on mammals, followed by birds, and then fish. Articles on basic biology are most common, although articles on conservation and species' geographic ranges are also common. CFN remains an important outlet for basic biology and conservation studies, and despite the decreasing trends in the number of articles published per year, CFN will likely remain a keystone publication for natural history in Canada.

Key Words: Meta-analysis; natural history; publication trends; temporal trends

Introduction

The Canadian Field-Naturalist (CFN) is an important outlet for peer-reviewed research on all aspects natural history (Mosquin 1970; Smith 1977; Callaghan 2011), from both professional and amateur authors (Mosquin 1970; Smith and Smith 1975; Smith 1979, 1980; Fitzsimmons and Skevington 2010). I specifically define natural history as observational, field-based studies of organisms. Natural history therefore includes many sub-disciplines of biology, including ecology, behaviour, biogeography, taxonomy, and conservation. CFN (including its predecessors) has been published since 1880 (Cook 1986; Brunton 2004), and serves as a continuous record of natural history in Canada. This is very important, especially for the conservation of species (Bury 2006), where the best information for status reports on species comes from natural history papers.

Despite the importance of natural history (Bury 2006; Callaghan 2011), there has been some suggestion that studies on natural history are becoming less common (Peters 1980; McCallum and McCallum 2006). Some authors suggest that naturalists are not disappearing, but are rather studying the natural world in the lab rather than in the field (Arnold 2003), while other authors believe that natural scientists are focussing their effort on more efficient and marketable studies that can be published in journals with higher impact factors (Lopez 2001). Given that CFN often has the lowest or one of the lowest impact factors of any journal in both categories in which it is ranked (Thomson Reuters 2016), it seems likely that authors choosing to publish in CFN do not care much about the impact factor of CFN (Fitzsim-

mons and Skevington 2010), but are rather publishing in CFN because it is an important outlet for natural history observations. In fact, the impact factor might not accurately depict the actual impact of CFN, because impact factors generally under-value field research (Taylor 1981), and CFN is also commonly cited in books, monographs, and reports, which are not counted towards the impact factor (W.D.H., personal observation). The current generation might even have less natural history knowledge and fewer natural history skills than previous generations (Stebbins and Cohen 1995; Bury 2006) that may have important implications for the future of natural history publications. It is also possible that researchers and amateur naturalists are sharing their natural history observations through other media, especially with increasing online communication in recent years. Authors might also be publishing their natural history observations in region-specific journals, such as *Northeastern Naturalist* or *Northwestern Naturalist*, or taxa-specific journals, such as *Journal of Mammalogy* or *Journal of Herpetology*, to reach their target audience.

Given the importance of natural history, and the general loss of natural history publications and knowledge, I examine publication trends for CFN between 1980 and 2015 to determine if the general reduction in natural history studies is affecting CFN. I also examine what types of articles are being published, and information about the types of authors that are publishing in CFN. I establish how CFN has aided in the record of natural history studies, and forecast CFN's role in the future.

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalists' Club.

Methods

I first collected page length for every volume of CFN published between 1920 and 2015 to put this study into historical perspective. I then collected metadata from every research article and note (henceforth referred to as articles) published in CFN between 1980 and 2015. Every CFN article from 2003 (volume 117 issue 2) and onwards is fully indexed and available online through the CFN website (<http://www.canadianfieldnaturalist.ca>). All articles from 1920 to 2010 are freely available from the Biodiversity Heritage Library (<http://www.biodiversitylibrary.org/bibliography/39970#/summary>). It should be mentioned that CFN also publishes book reviews, editorials, editor reports, annual reports and financial statements from the Ottawa Field-Naturalists' Club, and a news and comment section, all of which are highly valuable contributions, but are not directly related to the trends that I am exploring for this study. For this reason, I do not deal with any trends related to these other publications.

I specifically collected metadata on the number of pages for each article, the number of authors, location, and affiliation, the number of different first affiliations (some authors had multiple affiliations) for all authors, and the number of different locations for all authors. I also recorded which taxa were studied, and the general topic of the study. I first subdivided taxa into vertebrates, invertebrates, plants, and other, and then subdivided vertebrates into classes (amphibians, birds, fish, mammals, and reptiles). I subdivided topics into six large categories: basic biology (behaviour, ecology, etc.), conservation (status reports and studies with direct conservation application), distribution (range extensions), methods, taxonomy, and reviews.

I analyzed all data in R version 3.2.1 using simple linear regression (package: stats; function: lm; R Core Team 2015). In all analyses, I regressed each variable by year to examine if publishing trends have changed through time. I included a polynomial effect of year when the relationship was not linear. In analyses of categorical variables (i.e., author location, taxa), I included the total number of articles published in one year for each level of the category as the dependent variable, and included year, the categorical variable, and their interaction as independent variables.

Results and Discussion

Volume length, number of articles published, and article length

The Canadian Field-Naturalist published relatively short volumes between 1920 and 1969 (mean \pm SE = 258 ± 7 pp), but due to an editorial decision (Mosquin 1970) began publishing much longer volumes from 1970 and onwards (583 ± 19 pp; Figure 1A). Although the volume length clearly increased between 1920 and 2015 (solid line on Figure 1A), volume length was relatively stable between 1920 and 1969, and between 1970 and 2015 (dashed lines on Figure 1A), although

there was significantly more variance in volume length between 1970 and 2015. These trends in volume length demonstrate the important impact of editorial decisions in publishing trends, and also serve as a reminder that past decisions will have an impact on all trends that I focus on for the remainder of this study.

The Canadian Field-Naturalist peaked in the number of articles published in 1988 with 126; the number of articles published generally decreased through time by 1.6 / year (line of best fit: $y = 3284.5 - 1.6x$; 95% $CI_{\text{slope}} = -2.11$ to -1.10 ; Figure 1B), with 56 fewer articles being published per year in 2015 than in 1980. This trend was best described by a polynomial equation ($r^2_{\text{adj}} = 0.66$), where the number of articles increased from 1980 to 1988, and then generally decreased from 1988 to 2015. The average length of articles increased through time at a rate of 0.05 more pages per article every year (line of best fit: $y = -98.68 + 0.05x$; 95% $CI_{\text{slope}} = 0.02$ to 0.08 ; Figure 1C; $r^2 = 0.28$); articles in 2015 had 2.5 more pages than those in 1980.

The trend in the number of articles published is partly caused by conservation status reports by the Fish and Marine Mammal Subcommittee of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) that were published in one issue per year from 1984 to 1993, 1996 to 1998, and in two issues in 2002. Indeed, the years with the highest number of articles published were also years with abbreviated COSEWIC status reports. These status reports were often published in addition to the regular number of articles in an issue. When COSEWIC decided to post full status reports on the internet (www.sararegistry.gc.ca), it relieved the CFN from any further role (F. Cook, personal communication), and the influx of extra articles was at an end. CFN has also had four special issues that each consisted of one article with much longer page lengths than normal that biased the average page length and number of articles during those years: in 1995 (66 pp; Pringle 1995), 1996 (254 pp; Cranmer-Bying 1996), 1997 (185 pp; Reddoch and Reddoch 1997), and 1999 (183 pp; Burnett 1999).

The number of articles published per year from 2010 to 2015 was still smaller than those published in the early 1980s by nearly 50 articles per year; therefore, there has still been a decreasing trend in the number of articles published when COSEWIC years are ignored. CFN faced a backlog of articles between 2005 and 2010 that lead to a lag in publication time and a subsequent sharp decrease in the number of articles published per volume (Figure 1A); volume length decreased from 649 pp in 2005 to 401 pp in 2008. This trend averaged around 410 pp per volume between 2008 and 2015, with small dips and increases around that trend. Even though CFN is currently publishing fewer articles than it did between 1980 and 2005, it is still publishing more articles and more pages per volume than before the editorial decision was made to increase volume length in 1970 (Mosquin 1970).

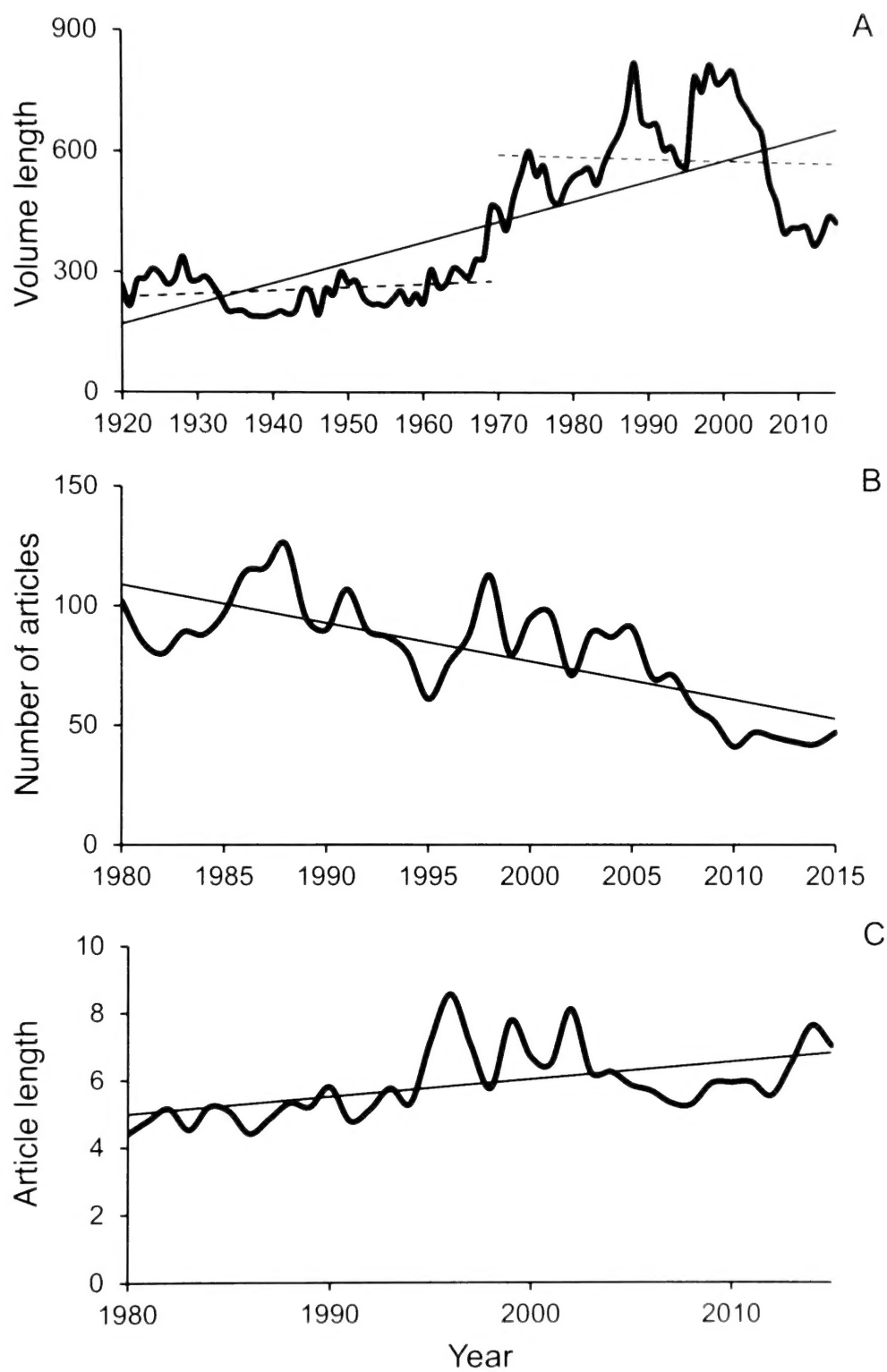


FIGURE 1. Volume length of *The Canadian Field-Naturalist* between 1920 and 2015 (A), and the number of articles published (B), and average article length (C) for all articles published in *The Canadian Field-Naturalist* between 1980 and 2015. Solid lines represent the line of best fit for the trend over the entire time period, and dashed lines in (A) represent trends over subsets of the time period.

In herpetology journals (*Herpetologica* and *Journal of Herpetology*), the number of natural history articles published per year has been decreasing, even though the total number of articles per year has been stable or increasing (McCallum and McCallum 2006). Many possible factors could have caused this change, including shifts in these types of publication to more regional journals, or that people are simply publishing their natural history observations less and focussing more energy and resources on experimental studies (Lopez 2001). Natural history observations may also be getting incorporated into larger publications that are then published in journals with higher impact factors. Because the number of articles published in CFN has been decreasing through time, it seems unlikely that natural history studies that were previously published in broader journals (such as the herpetology journals) are being published in CFN. Rather, it seems likely that the same factors causing fewer natural history articles in other journals are similarly affecting CFN. Despite the decreasing trend in the number of articles published, individual articles have been getting longer through time. It is possible that authors are publishing more data per article, are grouping multiple natural history observations together into one article, or are including more complicated analyses and models than in earlier years.

It is also possible that the decreasing trend in the number of articles being published in CFN is being caused by editorial decisions, including ability to handle workload and funding available to publish a certain number of pages per volume. Special issues and COSEWIC status reports, both of which increased the number of articles published and volume page length in the earlier years, each likely came with extra funding to cover publication costs. At this time, it is impossible to say what is causing this trend. Future work could examine the number of submissions to CFN, along with editorial decisions (rejection and acceptance rates), to determine whether authors are submitting fewer articles to CFN, and if this is the mechanism causing fewer articles to be published through time.

Taxa

The majority of articles published in CFN focussed on vertebrates, with a much smaller number of articles focussing on invertebrates and plants; only one article studied protists, eight articles studied fungi, 26 articles discussed entire ecosystems, and 49 articles were not related to living things over the 36 year span of this review. Articles on vertebrates decreased by 0.7 articles per year, whereas the number of articles on invertebrates and plants did not change as time progressed (Figure 2A; $r^2_{adj} = 0.85$).

Within vertebrate taxa, the most articles were published on mammals, followed by birds and then fish; a small number of articles were published on amphibians and reptiles. The number of articles published on birds decreased the most with time, at a rate of 0.5 articles per year (Figure 2B; $r^2_{adj} = 0.86$). The number of arti-

cles published on mammals decreased by 0.37 articles per year, and the number of articles on fish decreased by 0.32 articles per year. The number of articles published on amphibians and reptiles did not change with time. Although there were 10× more articles on fish than amphibians and reptiles from 1980 to 1990, the number of articles on fish has been very similar to the number of articles on amphibians and reptiles from 2005 onwards. The number of articles on herptiles (amphibians and reptiles combined) are published at similar rates to studies on plants and invertebrates.

The Canadian Field-Naturalist is clearly a popular outlet for natural history observations focussed on vertebrate animals. Most of the mammals that are studied are large and easy to observe, and birds are equally easy to observe (if not easier) for natural history observations. Secretive species, such as amphibians, reptiles, and invertebrates, are reported upon much less. Fish observations are often related to conservation or distribution (as in the earlier-mentioned COSEWIC reports), so despite the increased effort required to observe fish, there has been greater incentive to publish articles on fish due to the COSEWIC reports.

Topic

Many articles focussed on the general biology of a species, such as behaviour, foraging and diet, the relationship between the organism and its environment, population dynamics, and interactions between species. Other articles focussed on the geographic range (distribution) and conservation of species. A small number of articles focussed on different methods for studying organisms, the taxonomy of organisms, and reviews, but these types of articles were uncommon. The number of articles focussing on conservation, methods, review, and taxonomy decreased by 0.18 articles per year, the number of articles on species' distribution decreased by 0.54 articles per year, and the number of articles on basic biology decreased by 0.78 articles per year (Figure 2C; $r^2_{adj} = 0.89$). CFN remains first and foremost an outlet for field observations of the biology of organisms, but is also commonly an outlet for conservation articles (COSEWIC reports) and notes on range expansion. The decreasing trend in conservation studies might simply be due to COSEWIC reports being published in CFN during the earlier years, but not in the later years: when peak years are ignored on Figure 2C, the trend in number of conservation articles published is relatively low and stable through the study period.

Number of authors, number of affiliations, and number of locations

The number of authors per article has increased by 0.027 per year (line of best fit: $y = -51.0 + 0.026x$; 95% $CI_{slope} = 0.021$ to 0.031 ; Figure 3A; $r^2 = 0.79$). There were two authors per article, on average, in 1980 and three authors per article in 2015. The number of first affiliations of authors has increased by 0.017 per

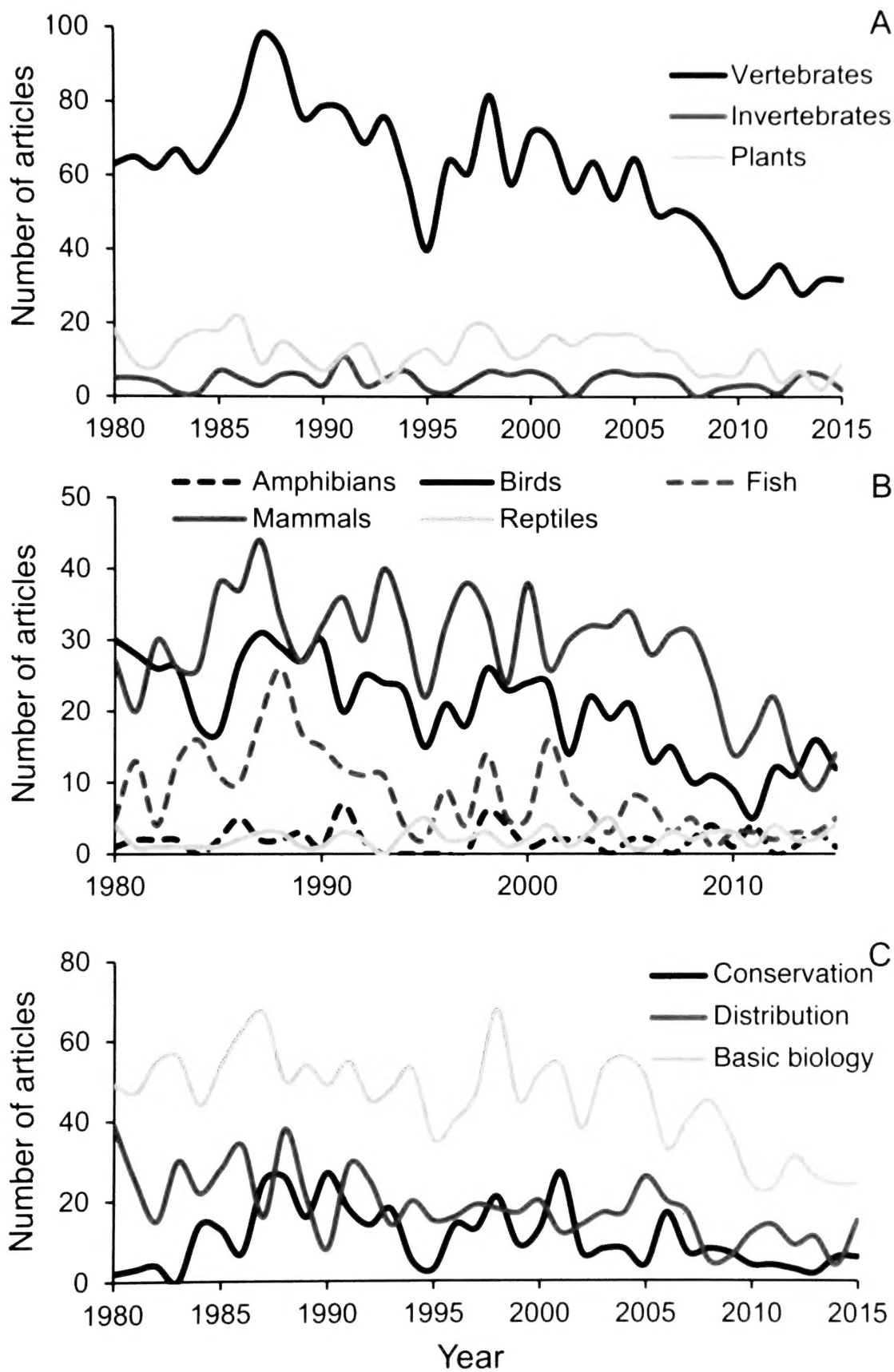


FIGURE 2. Number of articles published in *The Canadian-Field Naturalist* between 1980 and 2015 that focussed on major taxa (A), specific vertebrate taxa (B), and on different topics (C).

year (line of best fit: $y = -31.4 + 0.017 x$; 95% $CI_{slope} = 0.012$ to 0.021 ; Figure 3B; $r^2 = 0.67$), or 0.7 more affiliations in 2015 (two affiliations) than in 1980 (1.3 affiliations). The number of locations for authors has increased by 0.012 per year (line of best fit: $y = -22.6 + 0.012 x$; 95% $CI_{slope} = 0.008$ to 0.016 ; Figure 3C; $r^2 = 0.56$), which amounts to 0.35 more locations in 2015 than in 1980.

Wuchty *et al.* (2007) suggested that articles with the highest quality and highest impact are published by

teams of people rather than by solo individuals because articles by teams are cited more than articles by solo authors. Wuchty *et al.* (2007) found that the number of authors per article in science and engineering has increased from 1.9 to 3.5 between 1955 and 2000. This equates to an increase of 0.036 more authors per article every year, which is very similar to the trend seen in CFN (0.027 more authors/article/year). It is therefore likely that the same factors that are causing the increased number of authors per article in the general

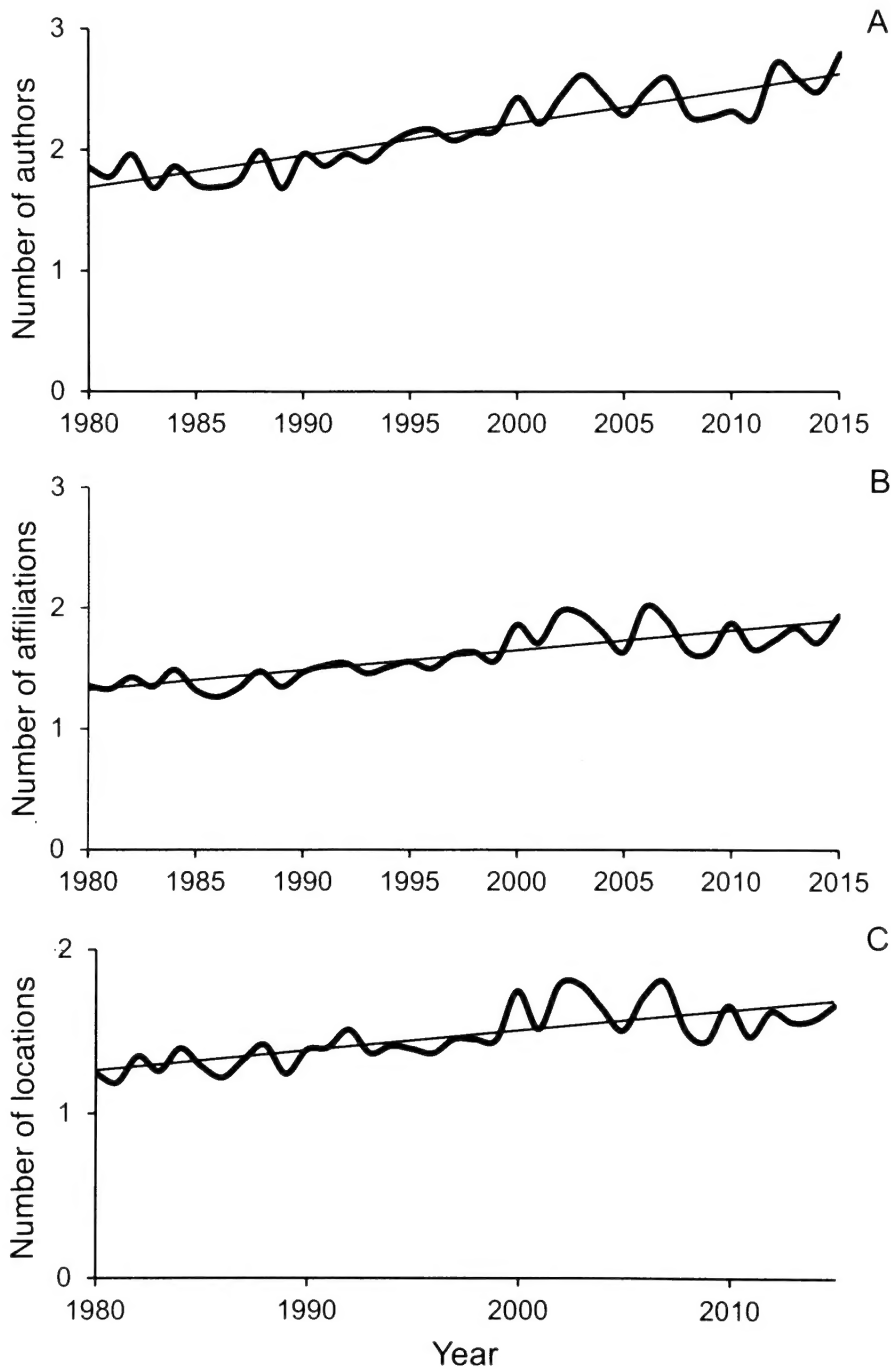


FIGURE 3. Number of authors (A), number of affiliations (B), and number of locations (C) for all articles published in *The Canadian Field-Naturalist* between 1980 and 2015. Solid lines represent the line of best fit for the trend.

realm of science and engineering (Wuchty *et al.* 2007) are similarly affecting authors in CFN.

Although the number of affiliations and locations did increase through time, the average increase is not very meaningful because it is less than one new affiliation or location between 1980 and 2015; the fact that the trend is statistically significant means that some more recent papers did have a greater number of affiliations and locations than older papers. The number of affiliations and locations are also highly correlated with the number of authors per article ($r = 0.73$ and 0.66 , respectively), therefore the increasing trend in the number of affiliations and locations per year might simply be an artefact of the increasing number of authors per year. Increased authors, affiliations, and locations are likely all related to a general trend of increasing collaboration among authors.

First author location and affiliation

More authors were from Canada than from other countries, although many authors were also from the

USA. The number of articles published by Canadian authors decreased sharply through time by 1.33 articles per year (line of best fit: $y = 2710.8 - 1.33 x$; 95% $CI_{slope} = -1.70$ to -0.95 ; Figure 4A; $r^2_{adj} = 0.91$); Canadian authors published roughly 100 articles per year in the 1980s, and this decreased to roughly 50 articles per year in the 2010s. Authors from the USA similarly published fewer articles with time, although the rate of decrease was only 0.34 articles per year (line of best fit: $y = 704.8 - 0.34 x$; 95% $CI_{slope} = -0.55$ to -0.14); authors from the USA published roughly 25 articles per year in the 1980s, and less than 20 articles per year in the 2010s. Authors from locations outside of Canada and the USA published rarely, and this trend did not change through time (line of best fit: $y = -70.3 + 0.04 x$; 95% $CI_{slope} = -0.019$ to 0.09).

Within Canada, the greatest number of authors was from Ontario. Many authors were also from Alberta, British Columbia, and Québec. All other provinces and territories had few and variable authors. Ontario had the

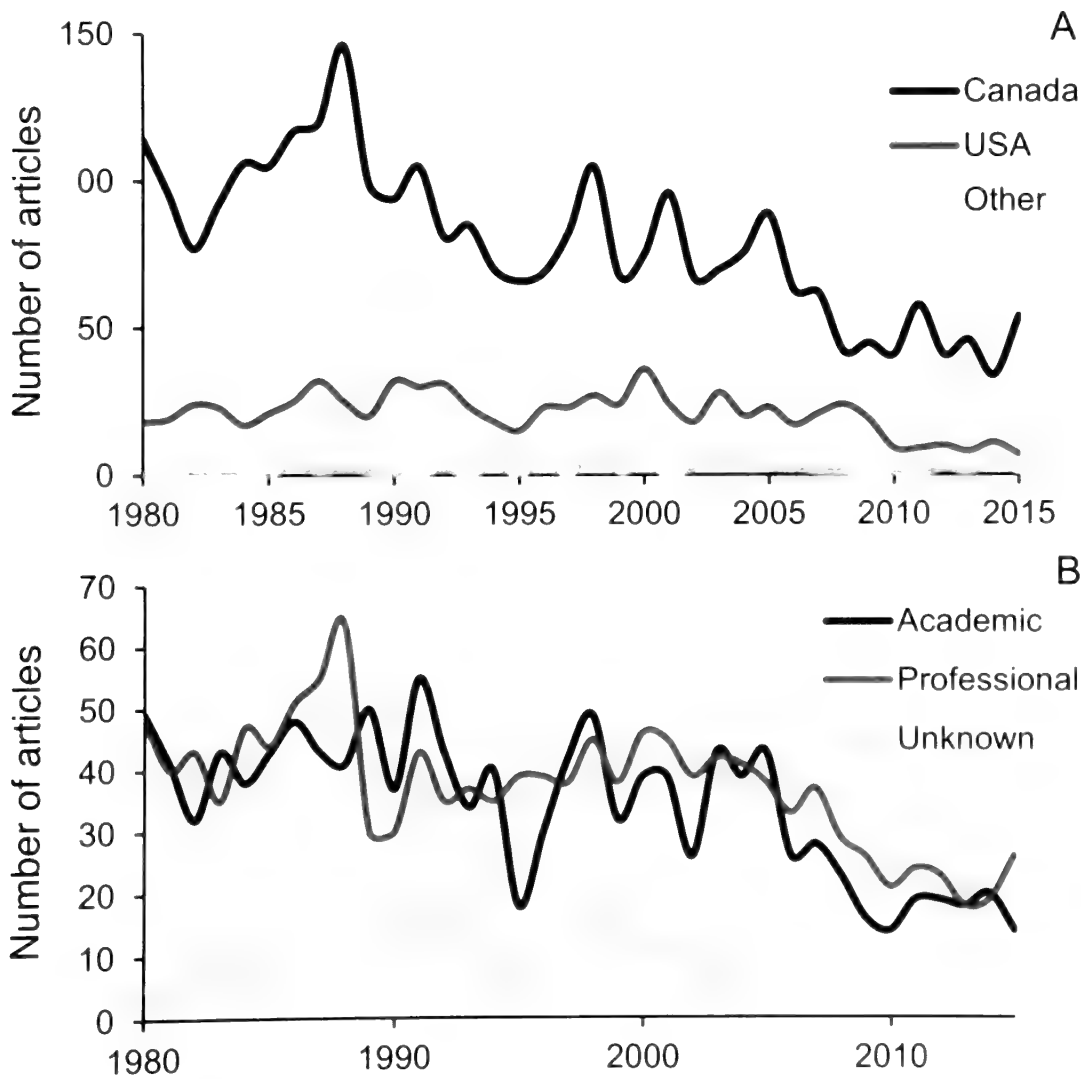


FIGURE 4. Number of articles published in *The Canadian Field-Naturalist* between 1980 and 2015 by authors in different locations (A) and with different affiliations (B).

strongest decrease in articles per year, followed by Alberta, Québec, and Manitoba; all other provinces and territories did not have a significant rate of change (Table 1). Within Ontario, roughly one third of authors were from the Ottawa region. Within Ottawa, the number of articles published decreased by 0.20 per year (line of best fit: $y = 400.5 - 0.20 x$; 95% $CI_{slope} = -0.28$ to -0.11), whereas in the rest of Ontario, the number of articles published decreased by 0.47 per year (line of best fit: $y = 945.8 - 0.47 x$; 95% $CI_{slope} = -0.64$ to -0.30). Articles published by authors from Ottawa decreased from 11 per year in 1980 to four per year in 2015, whereas in the rest of Ontario, articles decreased from 23 articles per year in 1980 to seven articles per year in 2015.

TABLE 1. Slope estimates for yearly number of articles published in *The Canadian Field-Naturalist* by authors from Canadian provinces and territories.

Province/Territory	Articles/Year
Alberta	-0.27*
British Columbia	-0.06
Manitoba	-0.10*
New Brunswick	0.01
Newfoundland and Labrador	-0.04
Northwest Territories	0.00
Nova Scotia	-0.03
Nunavut Territory	0.00
Ontario	-0.66*
Prince Edward Island	0.00
Québec	-0.11*
Saskatchewan	-0.04
Yukon Territory	0.03

*Represents a statistically significant rate of change, where the 95% CI does not overlap with 0.

Authors were just as likely to be from an academic (university or college) or professional (government and non-government) affiliation, and a small number of authors did not provide affiliation information or provided their home address. The number of academic authors decreased through time by 0.79 articles per year (line of best fit: $y = 1622.0 - 0.79 x$; 95% $CI_{slope} = -1.06$ to -0.53), and the number of professional authors decreased through time by 0.65 articles per year (line of best fit: $y = 1339.9 - 0.65 x$; 95% $CI_{slope} = -0.90$ to -0.41 ; Figure 4B; $r^2_{adj} = 0.80$), whereas the number of authors with an unknown affiliation decreased by 0.16 articles per year, although this decrease was not statistically significant (line of best fit: $y = 322.6 - 0.16 x$; 95% $CI_{slope} = -0.32$ to 0.01).

Given that CFN is a Canadian journal that specifically publishes articles about Canadian species, and issues that are relevant to Canadian species, it is logical that the majority of authors are Canadian, and that a smaller subset are from the USA that has many of the same species as Canada. Almost all authors from outside of Canada and the USA collaborated with a Canadian author or studied a species in Canada.

Within Canada, most authors were from the provinces with the largest populations (Ontario, Québec, Alberta, and British Columbia). Within Ontario, many authors (roughly one third) were from Ottawa, even though less than 10% of the Ontario population resides near Ottawa (Ottawa-Gatineau 2015 population = 1.3 million, Ontario 2015 population = 13.8 million; Statistics Canada 2016). Authors from Ottawa likely feel some connection to CFN because it is affiliated with the Ottawa Field-Naturalists' Club, and thus has ties to the local area. Indeed, many authors from Ottawa may also be members of the Ottawa Field-Naturalists' Club. Ottawa is also a hub for government employees, and contains multiple research-intensive agencies that employ scientists that study different aspects of natural history.

Similar numbers of authors were from academic and professional affiliations, which suggests that CFN is an important outlet for natural history professionals. This is vastly different from some other journals that cater almost wholly to academics (W.D.H., personal observation). Although there were low numbers of authors that did not provide affiliation information, it is possible that many of these authors are either amateur naturalists, or professional scientists that conducted studies unrelated to their job, and therefore collected data and wrote manuscripts on their own time. Indeed, CFN has been an important outlet for natural history observations by amateur naturalists since its inception (Cook 1986; Brunton 2004), and many editors have strived to continue the tradition of having CFN as an outlet for both professional scientists and amateur naturalists (Mosquin 1970; Smith 1977, 1979, 1980). Unaffiliated authors are also the only group that are not significantly decreasing their number of contributions through time. This lack of trend is important, especially because CFN was losing unaffiliated authors between the 1950s and 1970s (Smith 1979).

Which articles are being published less?

The general trend of fewer articles being published every year was seen in each subsequent analysis. Categories that were common, such as Canadian authors, vertebrate articles, and basic biology articles, all had the strongest decrease in the number of articles per year. In fact, the only categories that did not decrease through time were the rare categories, such as international authors and non-vertebrate taxonomic groups, and the only significant increase through time was in the number of authors per paper (and their affiliations and locations).

Conclusions

The Canadian Field-Naturalist is clearly a dynamic publication, as demonstrated by these temporal trends in publication patterns. Fewer but longer articles are being published every year. More authors per paper with greater collaboration are publishing every year. The majority of authors are Canadian and with either

an academic or professional affiliation. Most studies focus on vertebrates, and most of these focus on mammals, followed by birds, and then fish. Studies on basic biology are most common, although articles on conservation and geographic ranges are also common. CFN has been an important outlet for many professional scientists, unlike many other journals that tend to be dominated by academic authors. CFN has also been an important outlet for articles on geographic range extensions and conservation status reports.

The Canadian Field-Naturalist has successfully been an outlet for recording various Canadian natural history observations for over 130 years, and despite the recent decrease in the number of articles published per year, CFN continues the tradition of publishing important observations about Canadian species. Future work should expand the time frame of these analyses to fully document the history of CFN. Authors should continue to submit their natural history observations to CFN, not only because these observations are incredibly interesting to other naturalists (both amateurs and professionals alike), but also because these records serve as an important baseline for the conservation of species (Bury 2006).

Acknowledgements

Thanks to J. Fitzsimmons for the inspiration for this study. I am also grateful to F. Cook, P. Catling, and one anonymous reviewer for helpful comments that improved the quality and clarity of this contribution. Francis Cook, previous editor of *The Canadian Field-Naturalist*, provided useful information on past editorial decisions in *The Canadian Field-Naturalist* on 15 July 2016.

Literature Cited

- Arnold, S. J.** 2003. Too much natural history, or too little? *Animal Behaviour* 66: 1065–1068. <https://doi.org/10.1006/anbe.2003.2143>
- Bury, R. B.** 2006. Natural history, field ecology, conservation biology and wildlife management: time to connect the dots. *Herpetological Conservation and Biology* 1: 56–61.
- Brunton, D. F.** 2004. Origins and history of the Ottawa Field-Naturalists' Club. *Canadian Field-Naturalist* 118: 1–38. <https://doi.org/10.22621/cfn.v118i1.879>
- Burnett, J. A.** 1999. A passion for wildlife: a history of the Canadian Wildlife Service, 1947–1997. *Canadian Field-Naturalist* 113: 1–183.
- Callaghan, C.** 2011. The importance of natural history and *The Canadian Field-Naturalist* to natural science. *Canadian Field-Naturalist* 125: 2–4. <https://doi.org/10.22621/cfn.v125i1.1119>
- Cook, F. R.** 1986. The “one hundredth” volume of the Canadian Field-Naturalist. *Canadian Field-Naturalist* 100: 140–142.
- Cranmer-Bying, J. L.** 1996. A life with birds. Percy A. Taverner, *Canadian Ornithologist*, 1875–1947. *Canadian Field-Naturalist* 110: 1–254.
- Fitzsimmons, J. M., and J. H. Skevington.** 2010. Metrics don't dismiss journals with a low impact factor. *Nature* 466: 179. <https://doi.org/10.1038/466179c>
- Lopez, B.** 2001. The naturalist. *Orion: People and Nature* 20: 38–43.
- McCallum, M. L., and J. L. McCallum.** 2006. Publication trends of natural history and field studies in herpetology. *Herpetological Conservation and Biology* 1: 62–27.
- Mosquin, T.** 1970. Editorial policy of the Canadian Field-Naturalist. *Canadian Field-Naturalist* 84: 3.
- Peters, R. H.** 1980. From natural history to ecology. *Perspectives in Biology and Medicine* 23: 191–203. <https://doi.org/10.1353/pbm.1980.0042>
- Pringle, J. S.** 1995. The history of the exploration of the vascular flora of Canada. *Canadian Field-Naturalist* 109: 291–356.
- R Core Team.** 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
- Reddoch, J. M., and A. H. Reddoch.** 1997. The orchids in the Ottawa district: floristics, phylogeography, population studies and historical review. *Canadian Field-Naturalist* 111: 1–185.
- Smith, L. C.** 1977. Editorial policy. *Canadian Field-Naturalist* 91: 117–121.
- Smith, L. C.** 1979. The Canadian Field-Naturalist – the status quo or a new direction? *Canadian Field-Naturalist* 93: 10–15.
- Smith, L. C.** 1980. Feedback on the roles of The Canadian Field-Naturalist. *Canadian Field-Naturalist* 94: 92–96.
- Smith, L. C., and D. A. Smith.** 1975. Looking ahead. *Canadian Field-Naturalist* 89: 1–4.
- Statistics Canada.** 2016. Summary tables. Accessed 15 July 2016. <http://www.statecan.gc.ca/tables-tableaux/sum-som/index-eng.htm>.
- Stebbins, R. C., and N. W. Cohen.** 1995. *A Natural History of Amphibians*. Princeton University Press, Princeton, New Jersey, USA.
- Taylor, R.** 1981. Is the impact factor a meaningful index for the rankings of scientific research journals? *Canadian Field-Naturalist* 95: 236–240.
- Thomson Reuters.** 2016. InCites journal citation reports. Accessed 13 July 2016. <https://incites.thomsonreuters.com>.
- Wuchty, S., B. F. Jones, and B. Uzzi.** 2007. The increasing dominance of teams in production of knowledge. *Science* 316: 1036–1039. <https://doi.org/10.1126/science.1136099>

Received 22 March 2016

Accepted 15 March 2017

A Population-level Analysis of Morning Song: Exploring the Implications for Point Counts

JENNIFER R. FOOTE^{1, 4, 5}, LAUREN P. FITZSIMMONS^{2, 5}, LYNNEA M. LOBERT¹, LAURENE M. RATCLIFFE³, and DANIEL J. MENNILL²

¹Department of Biology, Algoma University, 1520 Queen Street East, Sault Ste. Marie, Ontario P6A 2G4 Canada

²Department of Biological Science, University of Windsor, 401 Sunset Avenue Windsor, Ontario N9B 3P4 Canada

³Department of Biology, Queen's University, 116 Barrie Street, Kingston, Ontario K7L 3N6 Canada

⁴Corresponding author: jennifer.foote@algomau.ca

⁵Authors contributed equally to the manuscript

Foote, Jennifer R., Lauren P. Fitzsimmons, Lynnea M. Lobert, Laurene M. Ratcliffe, and Daniel J. Mennill. 2017. A population-level analysis of morning song: exploring the implications for point counts. *Canadian Field-Naturalist* 131(1): 10–18. <https://doi.org/10.22621/cfn.v131i1.1779>

Point counts are widely used for conducting ecological surveys of wild birds. Vocal output of birds varies with time of day, and therefore the results of ecological surveys should also vary with time of day. We modeled how males' singing rates change over the morning. We calculated song rates in 3 min sampling periods (the standard sampling period used by the North American Breeding Bird Survey) and compared how detection rates vary as sampling period increases. We recorded singing activity in 15 neighbourhoods of breeding Black-capped Chickadees (*Poecile atricapillus*) with 16-element microphone arrays that recorded every song from every male in every neighbourhood. We calculated the proportion of males that produced one or more songs during 3, 5, and 10 min count periods between nautical twilight and late morning. Our results show a strong peak in singing activity just before sunrise followed by a steady decline in singing activity over the course of the morning. We found that longer sampling periods yielded significantly higher detection rates at all times after sunrise. After sunrise, detection rates never exceeded 60%, even with 10 min sampling periods. We found that unpaired males had significantly higher detection rates than paired males but we found no difference between paired males with fertile versus incubating mates. Our results provide strong evidence that, for Black-capped Chickadees, surveys during the dawn chorus provide the most comprehensive assessment of the number of birds present, and that longer sampling periods yield significantly better estimates of population sizes at all times after sunrise.

Key Words: Acoustic location system; Black-capped Chickadee; dawn song; detection rate; point count

Introduction

The heightened vocal output from birds in the early morning offers an excellent opportunity to conduct point-count surveys. The North American Breeding Bird Survey, for example, is an annual survey used to study population changes over time (Link and Sauer 1998). Point counts are used by many agencies around the globe to estimate the abundance and diversity of birds (e.g., BirdLife International/European Bird Census Council 2000; Urfi *et al.* 2005). Breeding Bird Surveys take place in the morning, between 30 min before sunrise and approximately 4 h after sunrise. At each stop all birds seen or heard within 400 m are counted during a 3 min interval (Ziolkowski Jr. *et al.* 2010). Survey data are widely used in analyses of bird population numbers, providing targets for conservation initiatives (Link and Sauer 1998). Surveys usually rely on aural detection (Brewster and Simons 2009), yet birds' vocal output varies throughout the day, and therefore detectability varies with the timing of point counts (Farnsworth *et al.* 2002; Alldredge *et al.* 2007). Population estimates using Breeding Bird Survey data often apply time-of-day adjustments to account for differences in detection rates over the course of a survey day

(Rosenberg and Blancher 2005). Corrections for time-of-day take into account peak numbers on a route and adjust average numbers to peak numbers simulating peak numbers continuing throughout the morning. The number of detected birds is then doubled assuming a single detected bird represents a pair (Rosenberg and Blancher 2005). Unfortunately, there are relatively few studies of diel singing rates to test the time-of-day adjustment values calculated from survey data, which may lead to inaccurate estimates of population size (Thogmartin 2010).

Point count survey length is positively correlated with the number of species detected and the number of birds detected (Scott and Ramsay 1981; Fuller and Langslow 1984). Recently, Matsuoka *et al.* (2014) assessed recommendations for survey length and survey detection distances and found problems with current techniques. In most surveys, one or both of the distance standards (e.g., 50 m radius and unlimited radius) or time standards (e.g., 0–3 min followed by 3–5 min intervals) were not applied. For studies that collected data during more than one time frame (e.g., a 3 min survey followed immediately by an additional 2 min survey), an increased survey length resulted in 25–65% higher detec-

tion rates (Matsuoka *et al.* 2014). Matsuoka *et al.* (2014) call for a return to previously recommended standards to improve the quality of survey data to allow for meaningful comparisons across studies and meta-analyses. Specifically, Matsuoka *et al.* (2014) argued that surveyors should record birds at two spatial scales (within 50 m of the observer and beyond 50 m from the observer) and two or three time scales (within a 0–3 min sampling window followed by additional 2 and 5 min sampling windows). Thompson (2002) highlighted the importance of testing detectability assumptions of count data using marked populations where estimates can be compared to true-population sizes, although this recommendation has rarely been implemented.

In this study, we performed analyses of singing behaviour in a breeding population of individually-marked Black-capped Chickadees (*Parus atricapillus*) using a 16-microphone array. We monitored our study population intensively over a six-month period from mid-winter until after the breeding season, and therefore we knew the exact number of animals in the recorded areas and the identities of each of the singers. Given that we knew the total number of males in each area where we collected recordings, we were able to quantify what proportion of the population was singing at regular sampling intervals across the morning. Our first objective was to assess how the number of singing males varied temporally over the course of the morning, and to calculate a time-of-day adjustment for Black-capped Chickadees using data from continuous passive acoustic sampling of their vocal behaviour. Our second objective was to examine how aural detection rates changed when the survey length increased from 3 min to 5 min and 10 min, and how those detection rate differences changed over the course of the morning. Our third and final objective was to evaluate how detection rates varied with the pairing status (bachelor males versus paired males) and the breeding status (males with fertile females versus males with incubating females) of the singers.

Methods

We studied a banded population of Black-capped Chickadees at the Queen's University Biological Station (44.567°N, 76.317°W), north of Kingston, Ontario, Canada from January to July, 2005–2007. Adult birds were captured in winter using treadle-traps baited with sunflower seeds. We banded adult Black-capped Chickadees with aluminum Canadian Wildlife Service bands as well as unique combinations of coloured leg bands (newly banded birds: $n = 149$ in 2005, $n = 236$ in 2006, $n = 61$ in 2007). Beginning in late April, we recorded dawn and morning songs of male Black-capped Chickadees using a custom built 16-microphone Acoustic Location System. For a detailed description of the Acoustic Location System, see Fitzsimmons *et al.* (2008).

Each 16-channel microphone array recorded a neighbourhood of males, encompassing an area of $\sim 160\,000\text{ m}^2$ (e.g., $400\text{ m} \times 400\text{ m}$). A “neighbourhood” consisted of a cluster of 5 to 10 breeding territories (6.66 ± 1.34 ; mean \pm SE) occupied by birds that were familiar with each other from their previous winter flock or nearby flocks. We focused our analysis on the males within each neighbourhood that had territories located centrally within the array of recording areas (32 males in 5 arrays in 2005, 34 males in 5 arrays each in 2006 and 2007). In the current analysis, we did not include males on the edge of our array recording areas (i.e., males whose territories were not entirely encompassed by our microphones) because we could not be certain that we recorded all of their songs. From 30 April to 14 May, 2005–2007, we recorded 15 chickadee neighbourhoods (five in each year) for 2–3 mornings per neighbourhood. Recordings began just before or at nautical twilight and continued throughout the morning until approximately 11:00 EST. Daily recordings averaged 365.9 ± 2.4 min in length.

Our analyses relied on acoustic monitoring of songs that are produced by male Black-capped Chickadees (Foote *et al.* 2010), and are the most common vocalization of this species during the breeding season. In contrast to the solely acoustic focus of our surveys, Breeding Bird Surveys also include visual detections in addition to acoustic detections. Yet given that bird detections are primarily aural during Breeding Bird Surveys (Brewster and Simmons 2009), and numbers are then doubled to determine the number of breeding individuals, we believe our acoustic data are comparable (Rosenberg and Blancher 2005).

We used Syrinx-PC sound analysis software (J. Burt, Seattle, Washington, USA) to view and annotate 16-channel spectrograms of array recordings. We selected one morning of recording from each neighbourhood and we annotated all chickadee songs using the frequency and time cursors in Syrinx-PC. Although point counts often focus on both songs and calls, we chose to focus on songs in this analysis, given that songs are the most conspicuous, far-reaching vocalization produced by Black-capped Chickadees during the breeding season. We used a combination of field notes and location information to identify singing males (as in Fitzsimmons *et al.* 2008; Foote *et al.* 2008). During the recording period, 3 to 5 observers took detailed notes of the time and location of males producing songs, identifying as many colour-banded birds as possible. During annotation of sound files, the identity and location of each singing male was approximated using time of arrival distances at the different recording channels, as well as song amplitude differences between the different channels. If male identity was ambiguous when comparing the approximate position to our field notes, we used ARRAYGUI in MATLAB (see Mennill *et al.* 2006) to triangulate the position of the singing bird to identify it. In addition, we regularly compared the fine-

structural features of the array-recorded songs to reference recordings we collected from males in the field; subtle differences in the spectral properties of male songs facilitate identification from spectrograms. The output from the annotation process in Syrinx-PC was a spreadsheet containing a time-stamped record of all songs produced by all males during recording. From these spreadsheets, we calculated the number of unique males singing in each 3 min, 5 min, and 10 min period, using rolling (overlapping) time bins. For each neighbourhood, we determined how many males held territories within the recorded area, and then calculated the proportion of singing males during sampling intervals relative to the total number of males in the neighbourhood. For males that we knew to be bachelors during the recordings ($n = 5$ males across the 15 recordings), we calculated the proportion of males singing in each 3 min interval, and we did the same for five randomly-chosen paired males for comparison. For 12 males from 2005 with confirmed nesting stage on the day of recording, we calculated the proportion of males singing for six males with a fertile mate on the day of recording (we determined fertile period as 2 d prior to egg laying until the penultimate egg was laid; Smith 1991) and the proportion of males singing for six males with incubating mates. We standardized the timing of songs by calculating them relative to morning nautical twilight. The absolute time of day would not be appropriate given that the timing of sunrise changes daily. We calculated the time of nautical twilight based on data for the nearest city (Kingston, Ontario, Canada, approximately 50 km due south) from the National Research Council of Canada (2014) Sunrise/Sunset Calculator.

We used logistic regression to analyze variation in the mean proportion of males singing over the course of the morning. The fixed factor was time (min past nautical twilight) and we ran separate regressions for the three sampling period lengths (3 min, 5 min, and 10 min). We calculated a time-of-day adjustment factor according to the methods described in Rosenberg and Blancher (2005); the adjustment is the ratio of peak detections to mean-detections across the morning. To compare detection rates as a function of the length of the sampling window, we compared the proportion of males recorded in 3 min periods to the proportions sampled in 5 min and 10 min periods using Wilcoxon Signed-Rank tests. To compare detection rates of paired and unpaired males and males with fertile and incubating mates, we calculated the mean proportion of males detected in 3 min count periods during each 30 min interval between nautical twilight and the time when the first of these males stopped singing (317 min after twilight). We used a linear model on log-transformed detection probabilities to test for an effect of time, pairing status or fertile stage, and an interaction between the two factors. For this analysis, we excluded the first data point, 30 min after twilight when most

birds had not yet begun to sing. We analysed data using JMP 11 (SAS Institute, Cary, North Carolina, USA). Values are reported as means \pm SE, and all tests were two-tailed.

Results

Our analyses of morning-long recordings of 15 neighbourhoods of Black-capped Chickadees reveal that the detection probability for males reached a peak prior to sunrise, and then declined steadily over the course of the morning (logistic regression: $\chi^2_1 = 113.6$, $P < 0.001$; Figure 1). The proportion of males singing was highest during the dawn chorus, before sunrise, when approximately 90% of males in the population produced song. The time-of-day correction factor was 3.6, calculated as the ratio of peak detections to mean detections, calculated from continuous sampling across the 15 Black-capped Chickadee neighbourhoods.

Lengthening the sampling window from 3 min to 5 min or 10 min led to a significant increase in the total proportion of males detected (3 versus 5 min: Wilcoxon test: $W_{80} = 1463.5$, $P < 0.001$; 3 versus 10 min: Wilcoxon test: $W_{37} = 370.5$, $P < 0.001$; Figure 2). Increasing from 3 min to 5 min periods resulted in $24.4 \pm 2.5\%$ more males detected, and increasing from 3 min to 10 min periods resulted in $69.7 \pm 6.4\%$ more males detected.

The proportion of males that were detected during longer sampling periods increased over the course of the morning (logistic regression: 3 versus 5 min: $\chi^2_1 = 10.6$, $P = 0.0011$; 3 versus 10 min: $\chi^2_1 = 11.51$, $P = 0.0007$; Figure 3; Table 1). However, after sunrise the proportion of males detected never exceeded 60% of all of the males in the neighbourhood, even with longer sampling periods of 5 or 10 min.

The proportion of unpaired males detected in 3 min sampling periods was higher after sunrise than the proportion of paired males detected (linear model: $r^2 = 0.65$, $F_{2,17} = 15.63$, $P = 0.0001$; Figure 4). Both pairing status ($F_{1,18} = 8.64$, $P = 0.0091$) and time-of-day ($F_{1,18} = 22.62$, $P = 0.0002$) were significantly related to detection probability; however, the interaction between time and pairing status was not significant and was not retained in the model. In 3 min sampling periods, we detected on average $40.0 \pm 0.07\%$ of unpaired males and $27.0 \pm 0.07\%$ of paired males. The proportion of males detected with fertile or incubating mates did not show a clear pattern (linear model: $r^2 = 0.50$, $F_{2,17} = 8.52$, $P = 0.0027$; Figure 5). Time-of-day ($F_{1,18} = 3.94$, $P = 0.0010$) was significantly related to detection probability (as above); however, pairing status did not relate to probability of detection ($F_{1,18} = 1.22$, $P = 0.24$) and the interaction between time of day and pairing status was not significant and was not retained in the model. In 3 min sampling periods, we detected on average $31.1 \pm 0.08\%$ of males with fertile mates and $36.0 \pm 0.08\%$ of males with incubating mates.

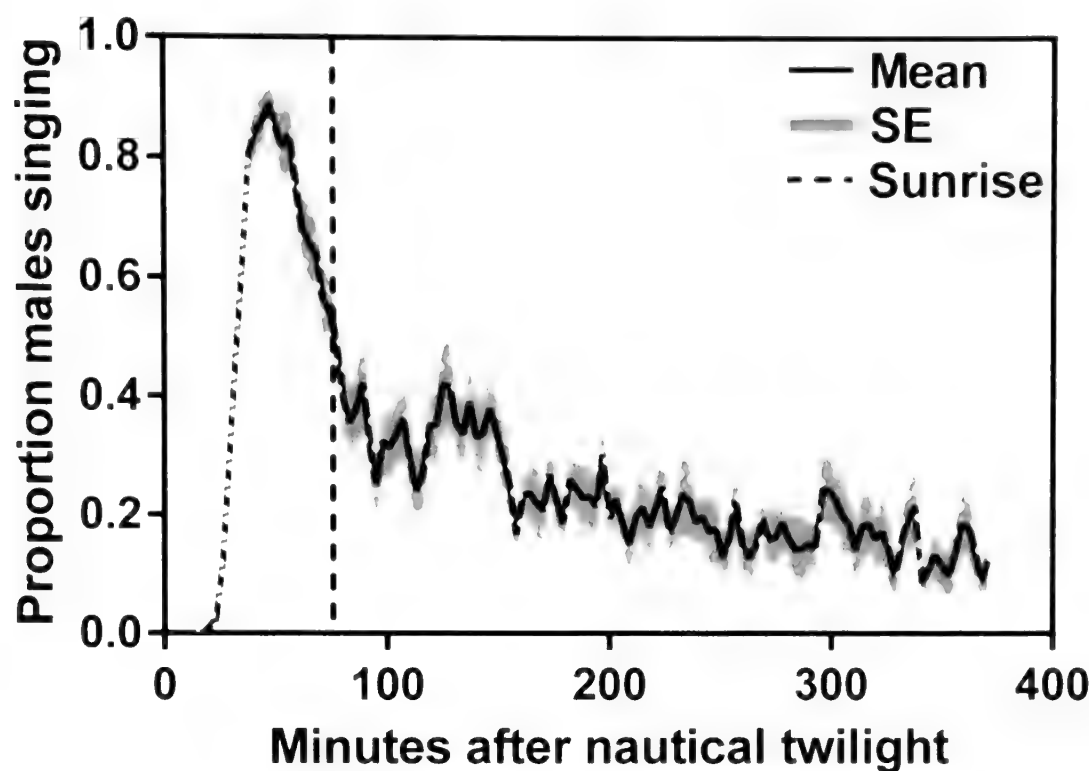


FIGURE 1. The mean (\pm SE) proportion of male Black-capped Chickadees (*Poecile atricapillus*) singing in 3 min sampling periods from nautical twilight through late morning.

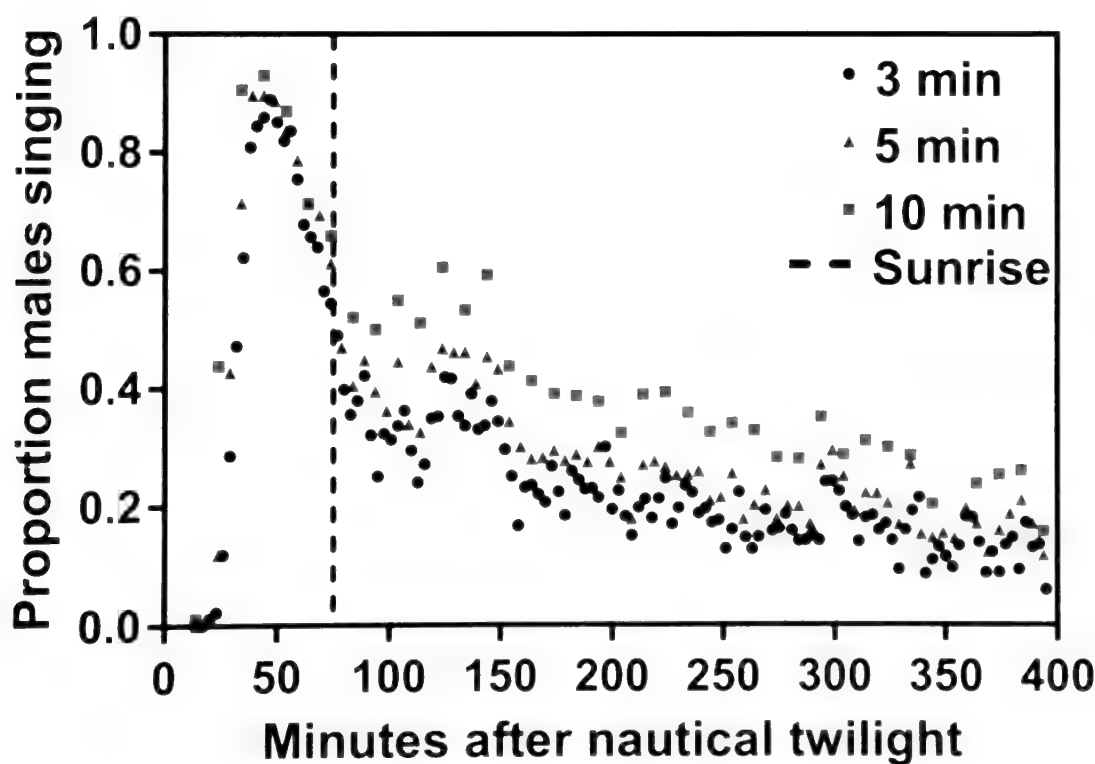


FIGURE 2. A comparison of detection rates of Black-capped Chickadees (*Poecile atricapillus*) with 3 min sampling periods (circle), 5 min periods (triangle), and 10 min periods (square) from nautical twilight through late morning.

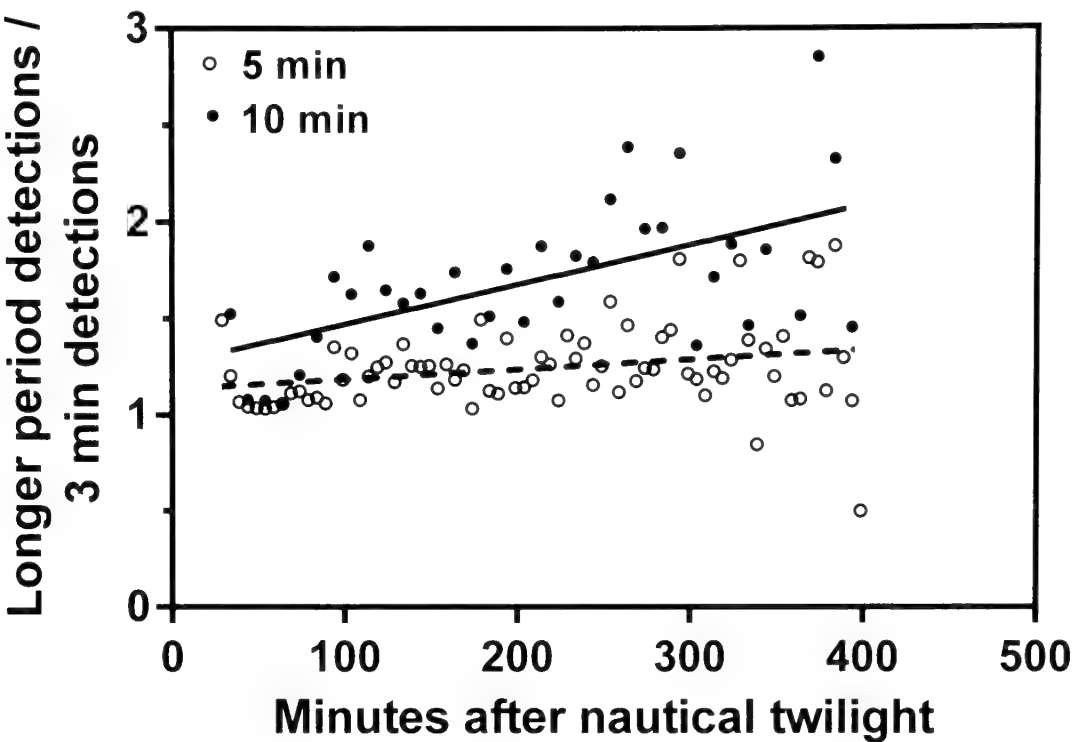


FIGURE 3. A comparison of detection rates of Black-capped Chickadees (*Poecile atricapillus*) between 3 min periods and 5 and 10 min periods. Points are the proportion of males detected during 5 min (open circles) and 10 min (filled circles) periods divided by the proportion of males detected during 3 min periods. Improved detection rates with longer sampling periods increase over the course of the morning.

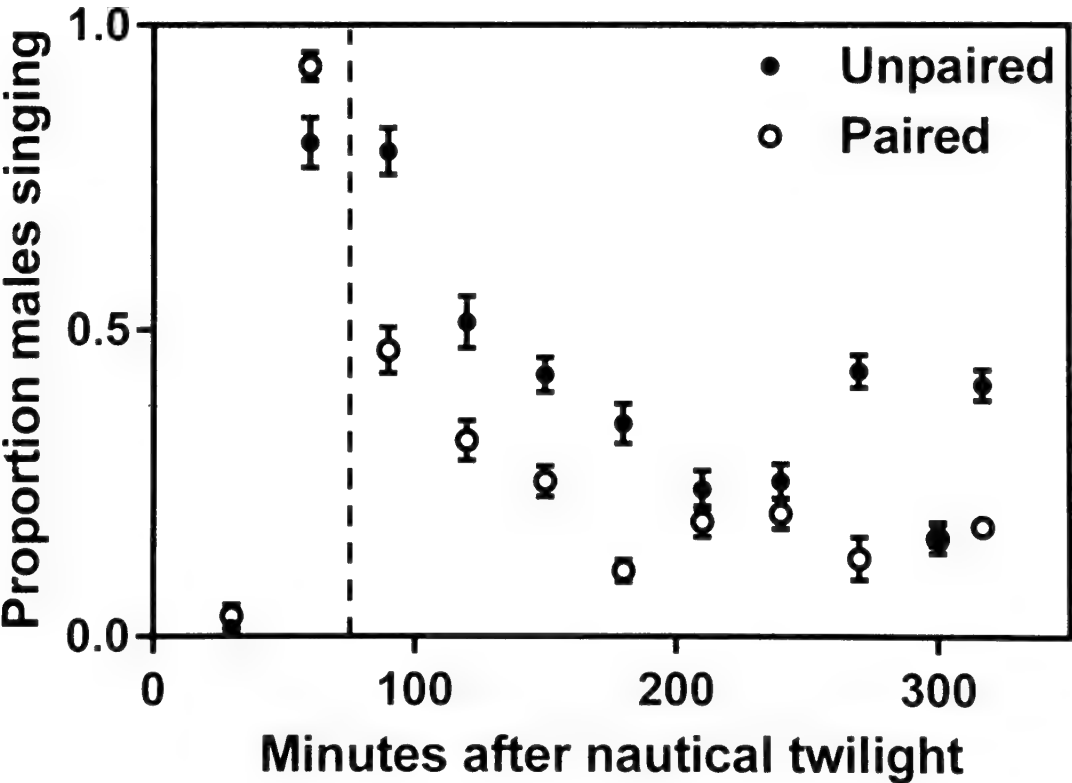


FIGURE 4. A comparison of detection rates of Black-capped Chickadees (*Poecile atricapillus*) during 3 min periods for unpaired males and paired males. Points represent the mean (\pm SE) proportion of males detected during 30 min bins from nautical twilight for 317 min (final bin is 17 min long) for five unpaired males (closed circles) and five paired males (open circles). The dotted vertical line shows the time of sunrise.

TABLE 1. Total number of Black-capped Chickadee (*Parus atricapillus*) detections for first 3 min (X^1), subsequent 2 min (X^2), and subsequent 5 min (X^3) of 10 min count periods, total detections (X) and total possible detections (N) in each of three morning periods.

	Counts			X	N^1	% detection ²
	X^1	X^2	X^3			
Before sunrise	329	33	53	415	507	81.85
Early morning*	361	57	130	548	1076	50.93
Late morning*	251	65	136	452	1301	34.74

*Following methods of Farnsworth *et al.* (2002), early morning is sunrise to 7:45am EST and late morning is 7:46 to 10:00 am EST.

¹Total possible detections is the sum of the number of males in the population in each 10 min interval.

² $X/N \times 100$.

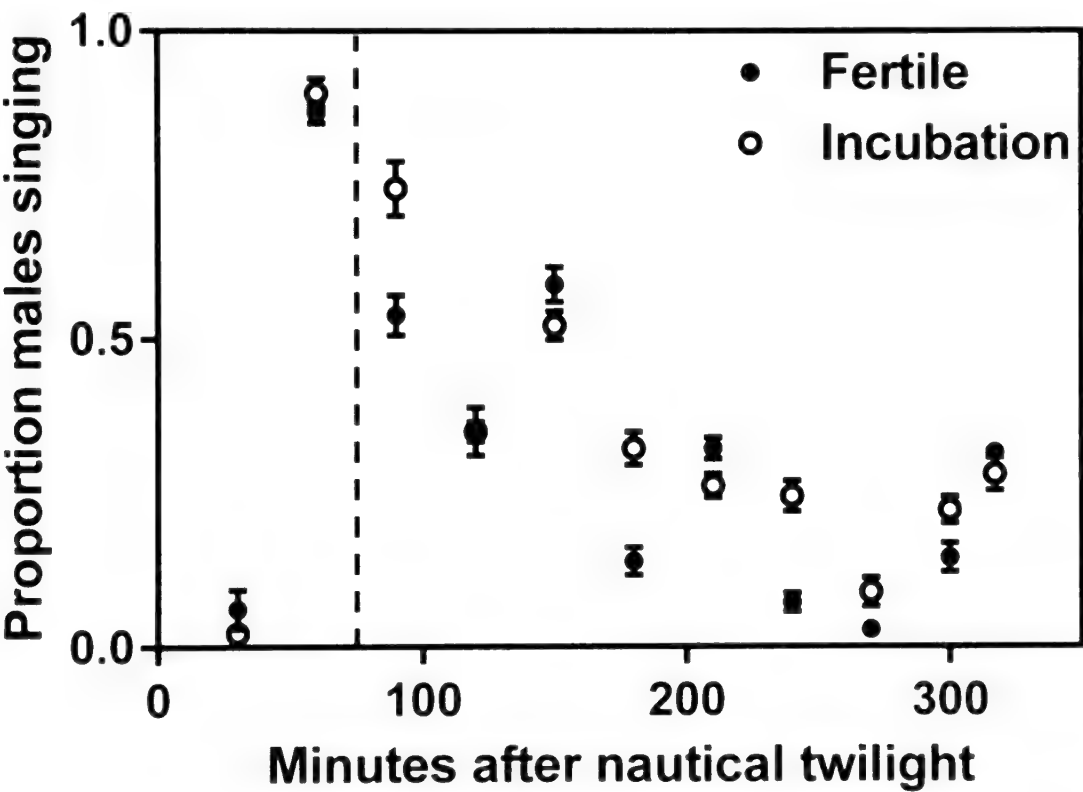


FIGURE 5. A comparison of detection rates during 3 min periods for male Black-capped Chickadees (*Parus atricapillus*) with fertile mates and males with incubating mates. Points represent the mean (\pm SE) proportion of males detected during 30 min bins from nautical twilight for 317 min (final bin is 17 min long) for six males with fertile females (closed circles) and six males with incubating females (open circles). The dotted vertical line shows the time of sunrise

Discussion

Microphone array recordings of 15 neighbourhoods of Black-capped Chickadees revealed a peak in singing activity before dawn, followed by a sharp decline in singing activity after dawn, followed by a more gradual decline over the course of the morning. Extending survey periods from the standard 3 min period to 5 min and 10 min periods resulted in 24% and 70% more males detected, respectively. The proportion of males that were detected during longer sampling periods increased over the course of the morning, but even with longer

surveys, detection rates after sunrise never exceeded 60% of the number of birds in the sampling area, and fell as low as 20% later in the morning. Unpaired males were detected 13% more often than were paired males in 3 min sampling periods, whereas males with fertile mates versus incubating mates were detected with similar frequency. Taken together, our results demonstrate that the most effective surveys can be conducted early in the morning (during the dawn chorus), and that sampling periods of 5 or 10 min provide a clear advantage over the standard 3 min period. Our results confirm the

importance of accounting for time of day when analysing and comparing survey data, and highlight that acoustic surveys sample an increasingly small subset of the population as the morning progresses.

Dawn versus daytime detectability

Black-capped Chickadees frequently engage in counter-singing interactions with territorial neighbours, both at dawn (Foote *et al.* 2008, 2010) and later in the morning (Fitzsimmons *et al.* 2008). After sunrise, counter-singing interactions may occur sporadically across the early morning period and our data show that song rates are much lower post-dawn. A decline in singing activity after the dawn chorus is seen in a number of other species with a distinct dawn chorus, with song rates ranging from 1–10% of the dawn maximum in an Australian community, for example (Keast 1985). Therefore, the pattern we observed with much higher output during the dawn chorus period is not specific to Black-capped Chickadees; this pattern is observed across diverse species (reviewed in Staicer *et al.* 1996). After dawn, our analyses reveal a steady decline in song rates and detection probabilities of Black-capped Chickadees. Given that we knew the population size in our recordings, we were able to calculate the exact detection probabilities; detection rates declined from 82% before sunrise, to 51% in early morning, to 35% in late-morning (Table 1). Similarly, Farnsworth *et al.* (2002; Table 1) found that thrushes and some warblers had lower detection probabilities in late morning compared to early morning, although vireos and other warblers did not.

Time-of-day correction factors

Time-of-day corrections calculated from focal studies have the potential to improve population estimates based on survey data, if we assume that all species exhibit a similar decline in detection probability as the morning progresses. We calculated a time-of-day adjustment value of 3.6 for Black-capped Chickadees in our study population. While we could not find a published value for Black-capped Chickadees, the median time-of-day correction value for diurnal landbird species calculated from North American Breeding Bird Survey data is 1.32, with a range from 1.04 to 22.3 (Rosenberg and Blancher 2005). Our correction value is higher than the published median, which indicates that our study yielded a higher ratio of peak detection rate to mean detection rate. A higher time-of-day correction factor for Black-capped Chickadees suggests that their abundance could be underestimated from Breeding Bird Survey data using a general landbird correction factor.

Our time-of-day correction could be higher than the median landbird value due to our continuous sampling with acoustic recorders providing a wider range of detection rates and/or higher peak detection rates before sunrise. However, the timing of our acoustic surveys coincides nicely with the timing of Breeding Bird Sur-

vey routes that are typically completed in 4 h beginning 30 min before sunrise by stopping at sites one after the other (Rosenberg and Blancher 2005; Ziolkowski Jr. *et al.* 2010). We recorded birds over three weeks during the peak of their breeding activity (early–mid May), whereas Breeding Bird Surveys sample birds over a longer six week period later in the season (end of May to early July). Black-capped Chickadees are early breeders (first egg date last week of April–first week of May at our study site; Foote *et al.* 2010), and thus detection probability based on song would likely be equal or lower in early to late season comparisons. However, this is more likely to lead to a higher, or at least equal, peak to average detection ratio later in the season because daytime song rates are likely higher during the early part of the breeding season compared to later in the season. Farnsworth *et al.* (2002) found that detection probability did not vary between early and late season for three of four focal species, with the fourth species displaying lower detection probability in early spring compared to late spring. Thus, the period of sampling in our study is likely representative of detectability across the spring. In two other studies of temperate songbirds, one species (Florida Grasshopper Sparrows, *Ammodramus savannarum floridanus*) showed variation in detection rates from day to day but did not vary synchronously across sites, whereas another species (Canada Warblers, *Cardellina canadensis*) did not show a strong influence of season (Hochachka *et al.* 2009; Demko 2012). Future studies should test seasonal shifts in detection probability as well as time-of-day shifts to determine if seasonal correction factors would also have utility. The discrepancy between the median diurnal landbird time-of-day correction factor and our results suggests that establishing species-specific correction factors is a worthwhile goal for future investigations. Incorporating time-of-day and date-specific detection rates for these species could be instrumental in refining population estimates. Automated recording systems could be used to create time-of-day correction factors for point counts given that point count detections are primarily aural. While the process of estimating species-specific correction factors may be labour intensive, it may be particularly useful for species-at-risk or species with relatively low density.

Survey length

We found that lengthening the sampling period provided better detection probabilities, matching closely the mean values calculated from surveys of 54 species reported in Matsuoka *et al.* (2014). However, the higher detection rates were not proportional to the longer sampling periods. This begs the question as to whether additional time spent sampling is worthwhile? North American Breeding Bird Survey routes, for example, use 3 min periods and make 50 stops. If the sampling periods were increased to 5 or 10 min each, it would have the effect of lowering the number of stops by 50% or more, which does not seem like a wise trade-off in

the interest of survey sampling at the continental scale as with the Breeding Bird Survey. For other surveys, though, Matsuoka *et al.* (2014) recently called for a unified return to previously recommended standards, including sampling in 3 min, 5 min, and 10 min periods during surveys. For traditional point-count surveys, these longer sampling periods require more time spent at each sampling location. They thus require more surveyors or more time to sample the same number of locations as shorter surveys but may result in more species detected as well as refined abundance estimates. Passive acoustic monitoring involves the continuous recording of an area that allows us to choose multiple subintervals of count period within the recordings, as suggested, without extra effort on the ground.

Social factors and detectability

We found that unpaired males were detected at significantly higher levels than paired males. Males sing to attract mates and also to defend territories against territorial rivals (Catchpole and Slater 2003) and, consequently, song rates of unpaired males are higher after sunrise compared to males that are already paired (reviewed by Møller 1991). There are few studies that directly test this effect on the detectability of birds during surveys. Similar to our results for Black-capped Chickadees, two other studies of temperate songbirds (Common Nightingales, *Luscinia megarhynchos*; Canada Warblers) show that unpaired males have a higher detection probability compared to paired males (Amrhein *et al.* 2007; Demko 2012). A third study compared population density estimates derived from aural detections for paired and unpaired males; in two temperate songbirds (Ovenbirds, *Seiurus aurocapilla*; Kentucky Warblers, *Geothlypis formosa*) 100% of unpaired males were detected but less than 65% of paired males were detected (Gibbs and Wenny 1993). Our results show that after sunrise, unpaired male Black-capped Chickadees are more likely to be detected than paired males (Figure 4). Although Breeding Bird Surveys are designed to estimate the number of breeding pairs, these collected findings demonstrate that acoustic surveys may overestimate the number of reproductive individuals when unpaired males are more likely to be detected. Thus, data on sex-ratio biases or the prevalence of unpaired territorial males may be an important factor to include in survey analyses. Unpaired territorial male Black-capped Chickadees are uncommon in our study population, however (five of 100 males in this study), and therefore we anticipate that pairing status would have only a small influence on abundance estimates. Species with higher sex-ratio biases with many singing unpaired males could have exaggerated abundance estimates due to the high probability of detecting unpaired individuals.

We found no obvious pattern of variation in detectability with breeding stage (males with fertile breeding partners versus incubating breeding partners). This suggests that early breeding stage has a negligible influ-

ence on detection rates in Black-capped Chickadees, despite lower overall song rates at dawn in males with fertile partners (Foote *et al.* 2008). However we did not consider later breeding stages. Within a species, levels of extra-pair paternity (Suter *et al.* 2009), paternal care (e.g., Stoehr and Hill 2000), mate guarding (Johnsen *et al.* 2003), breeding synchrony (van Dongen 2008), territory density (e.g., Sexton *et al.* 2007), and pairing status (e.g., Hennin *et al.* 2009) can result in substantial variation in song output. It would be interesting to better understand whether consistent singing patterns exist across species with similar life-history traits such that correction values could vary with these factors.

Acknowledgements

We thank J. Baldock, T. Barran, R. Bull, S. Doucet, D. Gabriel, H. Hennin, R. Jamieson, S. Lippold, A. McKellar, A. Osmun, D. Potvin, C. Toth, and K. Winger for assistance with field work. We thank the Curtis, Lundell, Warren, Weatherhead-Metz, and Zink families for access to property, and the staff of Queen's University Biological Station for logistical support. We thank J. Burt for software design. We thank Charles Francis, two anonymous reviewers, and the Associate Editor for comments that improved the manuscript. This research was funded by the Natural Science and Engineering Research Council of Canada, the Canada Foundation for Innovation, the Ontario Government, the Society of Canadian Ornithologists, the American Ornithologists Union, the American Museum of Natural History, the University of Windsor, Queen's University, and the Algoma University Research fund.

Literature Cited

- Allredge, M. W., T. R. Simons, and K. H. Pollock. 2007. Factors affecting aural detections of songbirds. *Ecological Applications* 17: 948–955. <https://doi.org/10.1890/06-0685>
- Amrhein, V., H. P. Kunc, R. Schmidt, and M. Naguib. 2007. Temporal patterns of territory settlement and detectability in mated and unmated Nightingales *Luscinia megarhynchos*. *Ibis* 149: 237–244. <https://doi.org/10.1111/j.1474-919X.2006.00621.x>
- BirdLife International/European Bird Census Council. 2000. European bird populations: estimates and trends. BirdLife Conservation Series No. 10. BirdLife International, Cambridge, UK.
- Brewster, J. P., and T. R. Simons. 2009. Testing the importance of auditory detections in avian point counts. *Journal of Field Ornithology* 80: 178–182. <https://doi.org/10.1111/j.1557-9263.2009.00220.x>
- Catchpole, C. K., and P. J. Slater. 2003. Bird Song: Biological Themes and Variations. Cambridge University Press, Cambridge, UK. <https://doi.org/10.1017/CBO9780511754791>
- Demko, A. 2012. Temporal and individual song variation in the Canada Warbler (*Cardellina canadensis*). M.Sc. thesis, Dalhousie University, Halifax, Nova Scotia, Canada.
- Farnsworth, G. L., K. H. Pollock, J. D. Nichols, T. R. Simons, J. E. Hines, and J. R. Sauer. 2002. A removal model for estimating detection probabilities from point-count surveys. *Auk* 119: 414–425. <https://doi.org/10.2307/4089888>

- Fitzsimmons, L. P., J. R. Foote, L. M. Ratcliffe, and D. J. Mennill.** 2008. Frequency matching, overlapping and movement behaviour in diurnal countersinging interactions of black-capped chickadees. *Animal Behaviour* 75: 1913–1920. <https://doi.org/10.1016/j.anbehav.2007.11.006>
- Foote, J. R., L. P. Fitzsimmons, D. J. Mennill, and L. M. Ratcliffe.** 2008. Tied to the nest: male black-capped chickadees decrease dawn chorus movement behaviour when their mate is fertile. *Animal Behaviour* 76: 1227–1233. <https://doi.org/10.1016/j.anbehav.2007.11.006>
- Foote, J. R., L. P. Fitzsimmons, D. J. Mennill, and L. M. Ratcliffe.** 2010. Black-capped chickadee dawn choruses are interactive communication networks. *Behaviour* 147: 1219–1248. <https://doi.org/10.1163/000579510X513761>
- Fuller, R. J., and D. R. Langslow.** 1984. Estimating numbers of birds by point counts: how long should counts last? *Bird Study* 31: 195–202. <https://doi.org/10.1080/00063658409476841>
- Gibbs, J. P., and D. G. Wenny.** 1993. Song output as a population estimator: effect of male pairing status. *Journal of Field Ornithology* 64: 316–322.
- Hennin, H.L., N. K. Barker, D. W. Bradley, and D. J. Mennill.** 2009. Bachelor and paired male rufous-and-white wrens use different singing strategies. *Behavioral Ecology and Sociobiology* 64: 151–159. <https://doi.org/10.1007/s00265-009-0832-4>
- Hochachka, W. M., M. Winter, and R. A. Charif.** 2009. Sources of variation in singing probability of Florida grasshopper sparrows, and implications for design and analysis of auditory surveys. *Condor* 111: 349–360. <https://doi.org/10.1525/cond.2009.080086>
- Johnsen, A., J. T. Lifjeld, and C. Krokene.** 2003. Age-related variation in mate-guarding intensity in the bluethroat (*Luscinia s. svecica*). *Ethology* 109: 147–158. <https://doi.org/10.1046/j.1439-0310.2003.00861.x>
- Keast, A.** 1985. Temporal vocalization patterns in members of a eucalypt forest bird community: the effects of weather on song production. *Emu* 94: 172–180. <https://doi.org/10.1071/MU9940172>
- Link, W. A., and J. R. Sauer.** 1998. Estimating population change from count data: application to the North American Breeding Bird Survey. *Ecological Applications* 8: 258–268. [https://doi.org/10.1890/1051-0761\(1998\)008%5B0258:EPCFCD%5D2.0.CO;2](https://doi.org/10.1890/1051-0761(1998)008%5B0258:EPCFCD%5D2.0.CO;2)
- Matsuoka, S. M., C. L. Mahon, C. M. Handel, P. Sólomos, E. M. Bayne, P. C. Fontaine, and C. J. Ralph.** 2014. Reviving common standards in point-count surveys for broad inference across studies. *Condor* 116: 599–608. <https://doi.org/10.1650/CONDOR-14-108.1>
- Mennill, D. J., J. M. Burt, K. M. Fristrup, and S. L. Vehrencamp.** 2006. Accuracy of an acoustic location system for monitoring the position of duetting tropical songbirds. *Journal of the Acoustical Society of America* 119: 2832–2839. <https://doi.org/10.1121/1.2184988>
- Møller, A. P.** 1991. Why mated songbirds sing so much: mate guarding and male announcement of mate fertility status. *American Naturalist* 138: 994–1014. <https://doi.org/10.1086/285264>
- National Research Council of Canada.** 2014. Sunrise/sunset calculator. Accessed 8 November 2013. <http://www.nrc-cnrc.gc.ca/eng/services/hia/sunrise-sunset.html>.
- Rosenberg, K. V., and P. J. Blancher.** 2005. Setting numerical population objectives for priority landbird species. Pages 57–67 in *Bird Conservation Implementation and Integration in the Americas: Proceedings of the Third International Partners in Flight Conference*. US Department of Agriculture, Forest Service General Technical Report PSW-GTR-191.
- Scott, J. M., and F. L. Ramsay.** 1981. Effects of abundant species on the ability of observers to make accurate counts of birds. *Auk* 98: 610–613.
- Sexton, K., M. T. Murphy, L. J. Redmond, and A. C. Dolan.** 2007. Dawn song of eastern kingbirds: intrapopulation variability and sociobiological correlates. *Behaviour* 144: 1273–1295. <https://doi.org/10.1163/156853907781890922>
- Smith, S. M.** 1991. *The Black-capped Chickadee: Behavioral Ecology and Natural History*. Comstock, New York, New York, USA.
- Staicer, C., D. Spector, and A. Horn.** 1996. The dawn chorus and other diel patterns in acoustic signaling. Pages 426–453 in *Ecology and Evolution of Acoustic Communication in Birds*. Edited by D. E. Kroodsma and E. H. Miller. Cornell University Press, Ithaca, New York, USA.
- Stoehr, A. M., and G. E. Hill.** 2000. Testosterone and the allocation of reproductive effort in male house finches (*Carpodacus mexicanus*). *Behavioral Ecology and Sociobiology* 48: 407–411. <https://doi.org/10.1007/s002650000247>
- Suter, S. M., D. Ermacora, N. Rieille, and D. R. Meyer.** 2009. A distinct reed bunting dawn song and its relation to extrapair paternity. *Animal Behaviour* 77: 473–480. <https://doi.org/10.1016/j.anbehav.2008.11.002>
- Thogmartin, W. E.** 2010. Sensitivity analysis of North American bird population estimates. *Ecological Modelling* 221: 173–177. <https://doi.org/10.1016/j.anbehav.2008.11.002>
- Thompson, W. L.** 2002. Towards reliable bird surveys: accounting for individuals present but not detected. *Auk* 119: 18–25. <https://doi.org/10.2307/4090008>
- Urfi, A. J., M. Sen, A. Kalam, and T. Meganathan.** 2005. Counting birds in India: methodologies and trends. *Current Science* 89: 1997–2003.
- van Dongen, W. F.** 2008. Mate guarding and territorial aggression vary with breeding synchrony in golden whistlers (*Pachycephala pectoralis*). *Naturwissenschaften* 95: 537–545. <https://doi.org/10.1007/s00114-008-0356-1>
- Ziolkowski Jr., D. J., K. L. Pardieck, and J. R. Sauer.** 2010. On the road again for a bird survey that counts. *Birding* 42: 32–41.

Received 19 April 2016

Accepted 8 November 2016

Note

Use of Camera Traps Provides Insight into the Feeding Ecology of Red Foxes (*Vulpes vulpes*)

CASEY J. WAGNON¹ and THOMAS L. SERFASS^{1,2}

¹Department of Biology, Frostburg State University, 101 Braddock Road, Frostburg, Maryland 21532 USA

²Corresponding author: tserfass@frostburg.edu

Wagnon, Casey J., and Thomas L. Serfass. 2017. Use of camera traps provides insight into the feeding ecology of Red Foxes (*Vulpes vulpes*). Canadian Field-Naturalist 131(1): 19–22. <https://doi.org/10.22621/cfn.v131i1.1950>

Red Foxes (*Vulpes vulpes*) often carry food items to caching sites and while making provisioning trips to litters. This behaviour provides opportunities to use camera traps to record Red Foxes carrying food that is likely prey. As part of a larger study using camera-trap surveys to monitor carnivore populations at Great Swamp National Wildlife Refuge, New Jersey, our cameras also recorded Red Foxes carrying food items allowing us to gain insight into the feeding ecology of this predator. Camera traps documented Red Foxes carrying food 71 times; items included mammals (78.9%), birds (19.7%), and fish (1.4%). Small mammals (unknown rodent or soricid species [23.9%] and voles [*Microtus* or *Clethrionomys* spp.; 5.6%]) were the most common groups of food items and Muskrat (*Ondatra zibethicus*; 15.5%) was the most common food item identified to species. Our surveys corroborate traditional diet assessments (e.g., scat analysis) of Red Foxes in North America, identifying them as a generalist forager that typically consumes smaller mammals. We also highlight the potential to apply camera trapping as a supplemental technique for gaining additional insight into the feeding ecology of this predator.

Key Words: Camera trap; diet; prey; Red Fox; *Vulpes vulpes*; Great Swamp National Wildlife Refuge

Identification of food remains in scats collected in the field and stomachs from carcasses of trapped individuals has been the primary source of dietary information for many species in the order Carnivora (Mills 1996; Klare *et al.* 2011), including the Red Fox (*Vulpes vulpes*; Doncaster *et al.* 1990; Sheldon 1992; Glen and Dickman 2008; Barrull *et al.* 2014). For example, Hockman and Chapman (1983) examined 128 Red Fox stomachs collected from trapped animals in Maryland during the autumn and winter seasons and concluded that Red Foxes primarily consumed small mammals (i.e., Meadow Voles [*Microtus pennsylvanicus*] and Eastern Cottontails [*Sylvilagus floridanus*]). Similarly, Ozoga *et al.* (1982) concluded that Deer Mice (*Peromyscus maniculatus*) and Meadow Voles were important food items identified in 367 Red Fox scats from Michigan's Upper Peninsula during the spring and summer. Red Foxes are generalist foragers and, in addition to consuming small mammals, have been reported to consume birds, fruits/seeds, invertebrates, carrion, and fish (Cypher 1982).

Camera-trap surveys are an effective method for investigating carnivore populations (Kays and Slauson 2008; O'Connell *et al.* 2011; McCallum 2013) and may offer a novel approach to document their feeding ecology. Red Foxes display foraging behaviours that may lend well to them being detected with food items by camera traps. For example, Red Foxes often cache prey instead of consuming it on site (Murie 1936; MacDonald 1976; Dekker 1983; Henry 1986; Larivière and Pasitschniak-Arts 1996) and, thus, travel from capture to cache sites with prey in the mouth. Also, Red Foxes have been reported to carry food to den sites during the pup-rearing season (Sargeant *et al.* 1984). Consequent-

ly, monitoring likely travel corridors (e.g., natural or human-made pathways) with camera traps may provide opportunities to detect and identify food being carried by Red Foxes (Ballard *et al.* 2014). As part of a larger study using camera-trap surveys to monitor carnivores occupying Great Swamp National Wildlife Refuge (GSNWR), Morris County, New Jersey (40°42'40.73"N, 74°27'52.82"W), we identified food items being carried by Red Foxes from our image dataset. Here we provide a description of taxa carried by Red Foxes and highlight the potential for using camera traps to gain insight into the diet of this predator.

From 24 November 2013 to 25 October 2014, 20 camera traps (Cuddeback Attack Flash and Capture Flash, De Pere, Wisconsin, USA) were located at intervals of 250–550 m to monitor the refuge's 10.5 km of service roads. Camera traps (in a Cuddeback Bear Safe, De Pere, Wisconsin, USA) were attached to wooden stakes (150 cm by 5.08 cm by 5.08 cm) placed approximately 1.5–2 m from the edge of the roads and at a height of 0.3–1 m off the ground. Camera traps were positioned perpendicular to roads and no bait or lure was used during the surveys (see Wagnon 2015 for complete details of methods).

In total, camera traps surveyed roads for 4866 camera trap nights (CTN). Survey effort was greater in summer (June, July, and August; 1581 CTN) and spring (March, April, and May; 1200 CTN) and less in autumn (September, October, November; 1064 CTN) and winter (December, January, and February; 1021 CTN). Camera traps recorded 2883 independent events involving Red Foxes (i.e., images of a fox at a site separated by > 60 min) for an average of 240.3 events month (range 35 in November 2013 to 528 in August 2014;

standard deviation 153.8). Among all Red Fox photos ($n = 3986$), 71 were of an individual animal carrying a food item. Red Foxes were photographed with food most frequently during the spring ($n = 40$) and summer ($n = 22$) and less frequently during autumn ($n = 1$) and winter ($n = 8$).

Food items were identified to the finest taxonomic level and the frequency of occurrence was calculated (i.e., number of images with the food item divided by the total number of images with food [$n = 71$] multiplied by 100). Food items represented three general taxonomic categories (i.e., mammal, avian, and fish; Table 1). Most of the food items were mammals (78.9%), comprising mainly unknown rodent or soricid species (23.9%), unknown mammals (23.9%), and Muskrats (*Ondatra zibethicus*, 15.5%; Figure 1, Table 1). However, Red Foxes were also recorded twice with a juvenile Raccoon (*Procyon lotor*; Figure 1), presumably examples of intraguild predation (Polis *et al.* 1989). Examples of Red Foxes carrying avian food items (birds 11.2% and eggs 8.5%) and a Largemouth Bass (*Micropterus salmoides*, 1.4%) were also represented in images (Table 1, Figure 1).

Similar to Red Fox scat/stomach analyses in North America, our image dataset indicates that Red Foxes are generalist foragers and frequently feed on mammals. During autumn, fruit/seeds may constitute 100% of their diet (Cypher 1982) and would not have been detected in our camera-trap images. Shifts in diet to fruits/seeds may explain the few events of foxes with food during autumn ($n = 1$), even though 730 events were recorded for that period. Moreover, adults would

no longer be engaged in provisioning trips after pups disperse in late summer and early autumn, likely reducing the chances of detecting Red Foxes with food. These examples demonstrate the limitations of camera traps in allowing comprehensive diet assessments for Red Foxes (and other wildlife). However, camera-trap surveys could complement traditional diet analyses (i.e., food identified in scats or stomachs) and provide additional details on the feeding ecology of Red Foxes. For example, egg predation would likely be missed or underestimated in traditional diet analyses, because foxes may only consume the nutrient-rich embryo and not the eggshell (i.e., the only evidence of egg predation discernible in scats or stomachs). Also, camera traps could provide useful insight into Red Fox consumption of species of management (e.g., rare, game, or invasive species) or economic interest (e.g., livestock). Our camera-trapping effort documented five incidents of Red Foxes with waterfowl, a group recognized as a management priority at GSNWR (United States Fish and Wildlife Service 2014). Further, our image dataset provided evidence of a potential ecological service carried out by Red Foxes; we documented three incidents of Red Foxes carrying a non-native rat (*Rattus rattus* or *R. norvegicus*), which are invasive species of considerable ecological concern (Maggs *et al.* 2015).

Examining the feeding ecology of Red Foxes was not the primary purpose of our study, but our camera-trap survey provided an opportunity to gain insight into Red Fox foraging habits through the unexpected collection of ancillary information. Our analysis under-

TABLE 1. The number and frequency of occurrence of food items carried by Red Foxes (*Vulpes vulpes*), and the total number of prey-carrying events recorded during camera-trap surveys at Great Swamp National Wildlife Refuge, New Jersey, from 24 November 2013 to 25 October 2014. Camera traps recorded 730, 296, 631, and 1226 independent events of Red Fox in the fall, winter, spring, and summer, respectively.

Food item	No. of records					%
	Fall ($n = 1$)	Winter ($n = 8$)	Spring ($n = 40$)	Summer ($n = 22$)	Total ($n = 71$)	
Mammals						
Unknown Rodentia or Soricidae	1	0	10	6	17	23.9
Unknown mammal	0	0	10	7	17	23.9
Muskrat (<i>Ondatra zibethicus</i>)	0	4	6	1	11	15.5
Vole (<i>Microtus</i> or <i>Clethrionomys</i> spp.)	0	0	4	0	4	5.6
Black or Brown Rat (<i>Rattus rattus</i> or <i>R. norvegicus</i>)	0	1	1	1	3	4.2
Eastern Cottontail (<i>Sylvilagus floridanus</i>)	0	1	1	0	2	2.8
Raccoon (<i>Procyon lotor</i>)	0	0	0	2	2	2.8
Total	1	6	32	17	56	78.9
Avian species						
Avian egg	0	0	6	0	6	8.5
Mallard (<i>Anas platyrhynchos</i>)	0	1	1	1	3	4.2
Unknown waterfowl	0	0	0	2	2	2.8
Wild Turkey (<i>Meleagris gallopavo</i>) poult	0	0	0	1	1	1.4
Rail (<i>Rallus</i> sp.)	0	1	0	0	1	1.4
Unknown bird	0	0	0	1	1	1.4
Total	0	2	7	5	14	19.7
Fish						
Largemouth Bass (<i>Micropterus salmoides</i>)	0	0	1	0	1	1.4

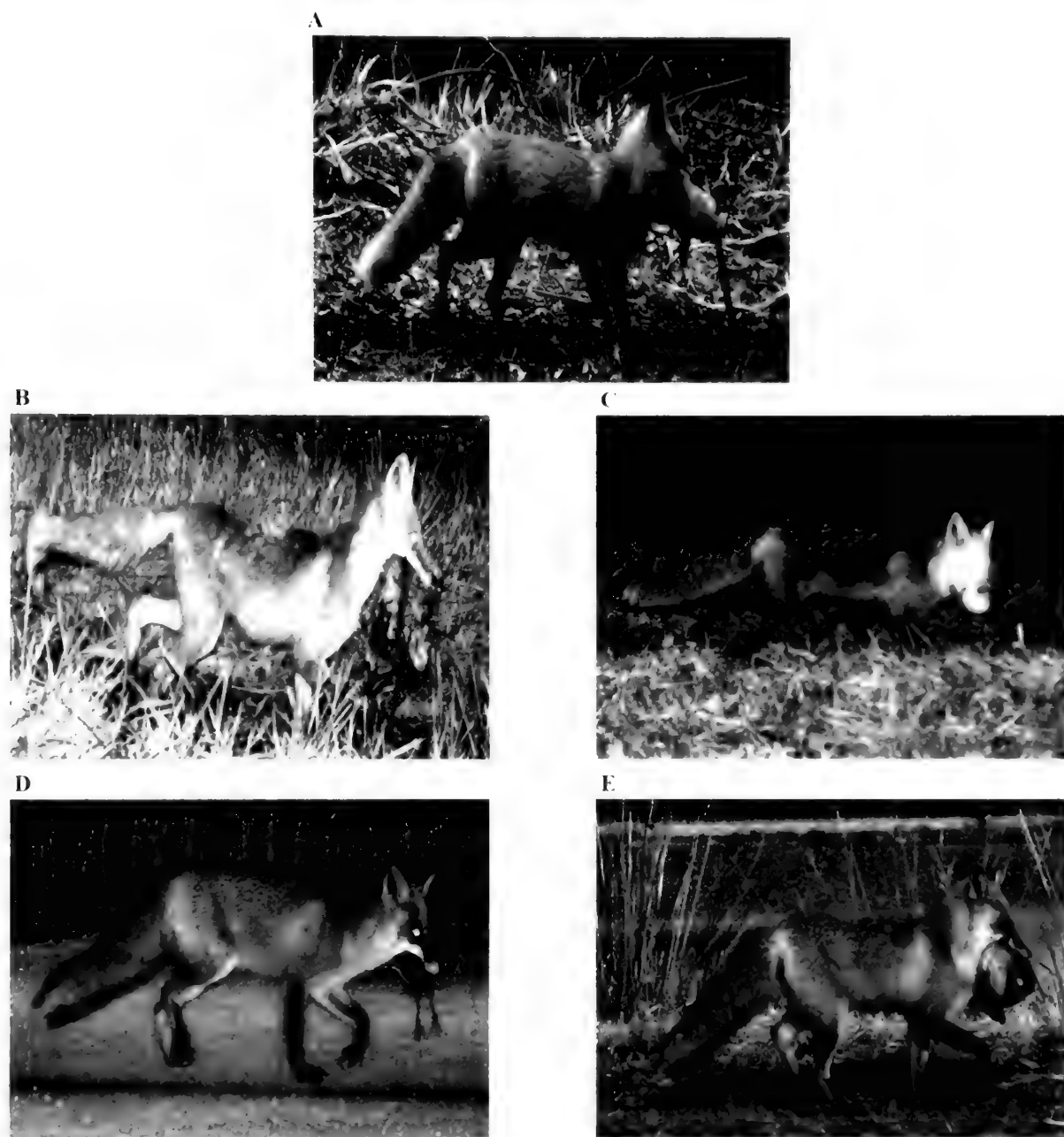


FIGURE 1. Images of Red Foxes (*Lilpes vulpes*) carrying food items recorded during camera-trap surveys at Great Swamp National Wildlife Refuge, Morris County, New Jersey, from 24 November 2013 to 25 October 2014. Prey items are (A) Muskrat (*Ondatra zibethicus*), (B) juvenile Raccoon (*Procyon lotor*), (C) avian egg, (D) Rail (*Rallus* sp.), and (E) Largemouth Bass (*Micropterus salmoides*). Photos: C. Wagon.

scores the value of camera traps in collecting data that may address interesting questions and natural history observations not directly related to the scope of a study.

Acknowledgements

This study received financial support from the Friends of Great Swamp National Wildlife Refuge, Basking Ridge, New Jersey, USA (Frostburg State University project 5159005). We thank this exceedingly generous group. We also thank the following United States Fish and Wildlife Service staff at GSNWR for

facilitating many logistical aspects of our study: D. M. Wells, D. Sagan, S. Henry, D. Miller, M. McMenamin, and J. Pimental. We thank Frostburg State University for providing logistic support and the two anonymous reviewers for greatly improving the manuscript.

Literature Cited

Ballard, G., P. D. Meek, S. Doak, P. J. S. Fleming, and J. Sparkes. 2014 Camera traps, sand plots and known events: what do camera traps miss? Pages 189–202 *in* Camera Trapping: Wildlife Management and Research, Edited by

- P. D. Meek and P. J. S. Fleming. CSIRO Publishing, Collingwood, Victoria, Australia.
- Barrull, J., I. Mate, J. Ruiz-Olmo, J. G. Casanovas, J. Gosálbez, and M. Salicrú.** 2014. Factors and mechanisms that explain coexistence in a Mediterranean carnivore assemblage: an integrated study based on camera trapping and diet. *Mammalian Biology* 79: 123–131. <https://doi.org/10.1016/j.mambio.2013.11.004>
- Cypher, B. L.** 1982. Foxes. Pages 511–546 in *Wild Mammals of North America: Biology, Management, and Conservation*. Edited by G. A. Feldhamer, B. C. Thompson, and J. A. Chapman. Second edition. Thompson Johns Hopkins, Baltimore, Maryland, USA.
- Dekker, D.** 1983. Denning and foraging habits of red fox, *Vulpes vulpes*, and their interactions with coyotes, *Canis latrans*, in Central Alberta, 1972–1981. *Canadian Field-Naturalist* 97: 303–306.
- Doncaster, C. P., C. R. Dickman, and D. W. Macdonald.** 1990. Feeding ecology of red foxes (*Vulpes vulpes*) in the city of Oxford, England. *Journal of Mammalogy* 71: 188–194. <https://doi.org/10.2307/1382166>
- Glen, A. S., and C. R. Dickman.** 2008. Niche overlap between marsupial and eutherian carnivores: does competition threaten the endangered Spotted-tailed Quoll? *Journal of Applied Ecology* 45: 700–707. <https://doi.org/10.1111/j.1365-2664.2007.01449.x>
- Henry, J. D.** 1986. Red Fox: The Catlike Canine. Smithsonian Institution Press, Washington, DC, USA.
- Hockman, J. G., and J. A. Chapman.** 1983. Comparative feeding habits of red foxes (*Vulpes vulpes*) and gray foxes (*Urocyon cinereoargenteus*) in Maryland. *American Midland Naturalist* 110: 276–285. <https://doi.org/10.2307/2425269>
- Kays, R. W., and Slauson, K. M.** 2008. Remote cameras. Pages 111–140 in *Noninvasive Survey Methods for Carnivores*. Edited by R. A. Long, P. MacKay, W. J. Zielinski, and J. C. Ray. Island Press, Washington, DC, USA.
- Klare, U., J. F. Kamler, and D. W. Macdonald.** 2011. A comparison and critique of different scat-analysis methods for determining carnivore diet. *Mammal Review* 41: 294–312. <https://doi.org/10.1111/j.1365-2907.2011.00183.x>
- Lariviere, S., and M. Pasitschniak-Arts.** 1996. *Vulpes vulpes*. *Mammalian Species* 537: 1–11.
- Macdonald, D. W.** 1976. Food caching by red foxes and some other carnivores. *Journal of Comparative Ethology* 42: 170–185.
- Maggs, G., M. Nicoll, N. Zuëlc, P. J. C. Whited, E. Winfield, S. Poongavananc, V. Tatayahc, C. Jones, and K. Norrissa.** 2015. *Rattus* management is essential for population persistence in a critically endangered passerine: combining small-scale field experiments and population modelling. *Biological Conservation* 191: 274–281. <https://doi.org/10.1016/j.biocon.2015.06.039>
- McCallum, J.** 2013. Changing use of camera traps in mammalian field research: habitats, taxa and study types. *Mammal Review* 43: 196–206. <https://doi.org/10.1111/j.1365-2907.2012.00216.x>
- Mills, M. G. L.** 1996. Methodological advances in capture, census, and food-habits studies of large African carnivores. Pages 223–242 in *Carnivore Behavior, Ecology, and Evolution*. Edited by J. L. Gittleman. Second volume. Cornell University Press, Ithaca, New York, USA.
- Murie, A.** 1936. Following fox trails. Miscellaneous publication 32. University of Michigan Press, Ann Arbor, Michigan, USA.
- O’Connell, A. F., J. D. Nichols, and K. U. Karanth.** 2011. *Camera Traps in Animal Ecology: Methods and Analyses*. Springer, New York, New York, USA.
- Ozoga, J. J., S. B. Craig, and L. J. Verme.** 1982. Red fox feeding habits in relation to fawn mortality. *Journal of Wildlife Management* 46: 242–243. <https://doi.org/10.2307/3808428>
- Polis, G. A., C. A. Myers, and R. D. Holt.** 1989. The ecology and evolution of intra-guild predation: potential competitors that eat each other. *Annual Review of Ecology and Systematics* 20: 297–330. <https://doi.org/10.1146/annurev.es.20.110189.001501>
- Sargeant, A. B., S. H. Allen, and R. T. Eberhardt.** 1984. Red fox predation on breeding ducks in Midcontinent North America. Wildlife monograph 89. Wildlife Society, Bethesda, Maryland, USA.
- Sheldon, J. W.** 1992. Genus *Vulpes*. Pages 162–203 in *Wild Dogs*. Edited by J. W. Sheldon. Academic Press, San Diego, California, USA, and London, United Kingdom.
- United States Fish and Wildlife Service.** 2014. Great Swamp National Wildlife Refuge comprehensive conservation plan. United States Department of Interior, Fish and Wildlife Service. Great Swamp National Wildlife Refuge, Basking Ridge, New Jersey, USA.
- Wagnon, C.** 2015. Surveying for carnivores with camera traps: an evaluation of carnivore detection patterns at Great Swamp NWR and the implications for camera-trap survey design. M.Sc. thesis, Frostburg State University, Frostburg, Maryland, USA.

Received 1 June 2016

Accepted 25 February 2017

Note

Extinguishing a Learned Response in a Free-ranging Gray Wolf (*Canis lupus*)

L. DAVID MECH

United States Geological Survey, Northern Prairie Wildlife Research Center, 8711 37th Street SE, Jamestown, North Dakota 58401-7317 USA; email: david_mech@usgs.gov or mechx002@umn.edu

Mech, L. David. 2017. Extinguishing a learned response in a free-ranging Gray Wolf (*Canis lupus*). *Canadian Field-Naturalist* 131(1): 23–25. <https://doi.org/10.22621/cfn.v131i1.1951>

A free-ranging Gray Wolf (*Canis lupus*), habituated to human presence (the author) on Ellesmere Island, Canada, learned to anticipate experimental feeding by a human, became impatient, persistent, and bold and exhibited stalking behaviour toward the food source. Only after the author offered the wolf about 90 clumps of dry soil over a period of 45 minutes in three bouts, did the wolf give up this behaviour. To my knowledge, this is the first example of extinguishing a learned response in a free-ranging wolf and provides new insight into the learning behaviour of such animals.

Key Words: Behaviour; *Canis lupus*; Ellesmere Island; extinguishing learned behaviour; Arctic; Gray Wolf; learned-response; learning

Learning and extinguishing learned behaviour (Thorndike 1911; Skinner 1953) have been well studied in domestic dogs (Miklosi 2015). Some investigations of learning have been conducted with captive Gray Wolves (*Canis lupus*; Packard 2003; Frank 2011), including one study that included extinguishing learned behaviour (Cheney 1982). In addition, considerable research has been done comparing social learning between dogs and captive wolves (Range and Viranyi 2013; Marshall-Pescini *et al.* 2015). However, to my knowledge, only Packard (2012) has studied learning in free-ranging wolves, and no one has investigated extinguishing a learned response in such wolves. The purpose of this study is to provide a detailed account of how I extinguished a learned response in a free-ranging wolf.

During the summers of 1986–2010, I made a series of observations of wolves on the Fosheim Peninsula of Ellesmere Island, Nunavut, Canada (80°N, 86°W; Mech 1987, 1988, 1995; Mech and Cluff 2011). Unlike those anywhere else in the world, the wolves in this remote region are unafraid of humans and can be observed from close range (< 1 m). Over 25 summers, my colleagues and I studied the behaviour of about 35 individual Arctic Grey Wolves (*Canis lupus arctos*). Their degree of tolerance toward us varied, but most would approach to within 5 m, while we were seated on all-terrain vehicles (ATVs). The main prey of these wolves are Muskoxen (*Ovibos moschatus*), Arctic Hares (*Lepus arcticus*), and Peary Caribou (*Rangifer tarandus pearyi*; Mech 1988).

In addition to observing the wolves' behaviour (Mech 1987, 1988, 1995), I also conducted various feeding experiments. In one such test, I threw weighed pieces of prey animals and other potential food items (e.g., Arctic Hare, Seal [*Phoca* spp.] meat, cheese, and dry

dog food) to breeding male members of packs after they had left their den of pups to go foraging. I wanted to determine how much food they would have to obtain to return to the den to feed their offspring. I tested small amounts of foods and found that the wolves would always accept various types of meat or prey parts, sometimes also cheese bits, and less often even dried dog food. Thus, I could gauge the degree of a wolf's hunger by which type of food it would accept (L.D.M., unpublished data).

Usually, I kept the food assortment in a 3–4-L plastic bucket hung from the handle bar of a four-wheeled ATV on which I always sat while observing the wolves. As a side effect of the feeding routine, the wolves learned that when I reached toward or into the bucket, they would get fed. Even on hearing the sound of touching or brushing against the bucket, the wolves would arise and approach me expectantly. Most often I did not feed them. Thus, the reinforcement was the variable-ratio type, in which a reward comes after an unpredictable number of responses. Whenever I did feed the wolves, they would wait around a few minutes after I stopped and resume whatever they had been doing before approaching me, most often sleeping or resting. Until the current observation, the wolves approached to within about 1–5 m, depending on the individual, and waited passively.

The observation that is the subject of this article was made in 1992, when the wolf pack consisted of an adult male wolf with his mate and three pups. Although the adult male bore no definitive identification marks, his behaviour toward me and toward the plastic bucket indicated that he was probably the same breeding male wolf ("Left Shoulder") that I had been observing each summer since 1986 (Mech 1995). During summer 1992, he was already showing the above-described,

conditioned response to the plastic bucket when I first approached him on 3 July 1992, and that continued throughout July.

The incident in which I extinguished an unusual response to my accessing the bait bucket occurred on 31 July 1992 at about 0920. The unusual aspects of the response to my feeding on this occasion were the wolf's impatience, persistence, stalking, and bold attempt to access the food source itself. During 25 summers of spending 2–4 weeks each year interacting with the wolves in this area, this was the only time I saw this aggressively bold behaviour. The following description is paraphrased from my field notes:

The male wolf arrived, and not wanting to let him nose around camp, I, on my ATV, lured him away. He acted very hungry and eagerly ate even dry dog food, but he soon started into his predation mode, running after the ATV with tail up and looking at the bait bucket. The minute I stopped, he came to within 1 m of the bucket and seemed to try to grab it. Each time, I'd throw some food to him, but, each time, he would immediately return and act the same way in a very alert mode, ears forward, very anticipatory. I gunned the engine, and the wolf pulled back 30–60 cm but he quickly habituated to that. Thus I was forced to throw him food even though I knew this just rewarded his behaviour. The instant I tried to move, he started his stalking behaviour. I gradually moved ~150 m, but he remained in the stalking mode, and I only ward him off by feeding him some 10–20 times. This continued for ~20 more minutes.

I tried various means to change the wolf's behaviour without just throwing him the food bucket, which held the seal meat. I switched the bucket from the left side of the ATV where the wolf was to the right side, but he just switched his stalk to the right side. I held the bucket on my lap, but he still seemed about to grab it. Once I took a handkerchief out of my coat pocket, and the wolf started eying my pocket.

The way I finally broke the wolf of his stalking was to put dirt clumps into the bucket, breaking small pieces off like food bits and showing each to him like food and then tossing it to him. He went after the piece each time, and a few times he grabbed and bit them and spit them out. I tried this about 50 times, and each time he would go after the clump. After 5–10 minutes of this, the wolf started to leave. When about 4 m away he stopped and resumed his stalk. I resumed throwing him only dirt clumps. After ~20 more, he started away again but returned once more. I threw more clumps, and he checked each.

Finally, the wolf trotted off ~200 m. As I drove off, he came running back and continued the same stalking behaviour. I continued throwing him dirt clumps, and he went after about 20 more. After ~5 minutes, he left, and I let him get ~200 m more away. I then left in the opposite direction at about 1030, and the wolf did not follow.

The adult male wolf's unusual behaviour toward the food bucket probably resulted from the combination of his being especially hungry and me feeding him to ward him off, which only rewarded him and encour-

aged his behaviour in a rapidly escalating learning situation.

It took approximately 90 offerings of dry soil clumps over about 45 minutes to extinguish the wolf's impatience, persistence, stalking behaviour, and bold response in trying to access food. These unrewarded feedings (negative punishment), some of which the wolf grabbed and bit (positive punishment), did not extinguish the animal's basic response to my accessing the bait bucket, as evidenced by his standard response the next day and following days. They only extinguished his more complex and extreme behaviour exhibited on 31 July. The wolf showed classic spontaneous recovery (Pavlov 1927) each time I began driving away, an indication that he was also conditioned to the ATV's sound or movement.

I had learned this approach to extinguishing an animal's response to artificial feeding by using it previously on a Long-Tailed Jaeger (*Stercorarius longicaudus*). I had been feeding this bird around our field camp until it became a nuisance. By feeding it an unrecorded, but high, number of soil clumps, I extinguished the bird's "begging" behaviour.

My observation has little relevance to the extinguishing of a captive wolf's response to the discrete-trial-probability learning experiments that Cheney (1982) conducted and, as it involved only a single wolf, it cannot necessarily be generalized. However, it does generally accord with the findings of Bentosela *et al.* (2008) about extinguishing learned responses and spontaneous recovery in domestic dogs, although those animals were on a fixed-ratio reinforcement regime. To my knowledge, this observation is the first example of extinguishing a learned response in a free-ranging wolf, and it provides new insight into the learning behaviour of such animals.

Acknowledgements

This study was funded by the United States Department of the Interior and the National Geographic Society. I also thank Environment Canada and the Polar Continental Shelf Project for logistical support. D. Cluff, H. Frank, T. S. Jung, J. M. Packard, Z. Viranyi, and J. Way provided helpful suggestions for improvement of an earlier draft of this article.

Literature Cited

- Bentosela, M., G. Barrera, A. Jakovcevic, A. M. Elgier, and A. E. Mustaca. 2008. Effect of reinforcement, reinforcer omission and extinction on a communicative response in domestic dogs (*Canis familiaris*). *Behavioural Processes* 78: 464–469. <https://doi.org/10.1016/j.beproc.2008.03.004>
- Cheney, C. D. 1982. Probability learning in captive wolves. Pages 272–281 in *Wolves of the World: Perspectives of Behavior, Ecology, and Conservation*. Edited by F. H. Harrington and P. C. Paquet. Noyes Publications, Park Ridge, New Jersey, USA. [https://doi.org/10.1016/0376-6357\(84\)90073-1](https://doi.org/10.1016/0376-6357(84)90073-1)
- Frank, H. 2011. Wolves, dogs, rearing and reinforcement: complex interactions underlying species differences in

- training and problem-solving performance. *Behavioural Genetics* 41: 830–839. <https://doi.org/10.1007/s10519-011-9454-5>
- Marshall-Pescini, S., Z. Viranyi, and F. Range.** 2015. The effect of domestication on inhibitory control: wolves and dogs compared. *PLoS ONE* 10:e0118469. <https://doi.org/10.1371/journal.pone.0118469>
- Mech, L. D.** 1987. At home with the Arctic Wolf. *National Geographic* 177: 562–593.
- Mech, L. D.** 1988. *The Arctic Wolf: Living with the Pack*. Voyageur Press, Stillwater, Minnesota, USA.
- Mech, L. D.** 1995. A ten-year history of the demography and productivity of an arctic wolf pack. *Arctic* 48: 329–332. <https://doi.org/10.14430/arctic1255>
- Mech, L. D., and H. D. Cluff.** 2011. Movements of wolves at the northern extreme of the species' range including during four months of darkness. *PLoS ONE* 6: e25328. <https://doi.org/10.1371/journal.pone.0025328>
- Miklosi, A.** 2015. *Dog Behaviour, Evolution, and Cognition*. Second edition. Oxford University Press, Oxford, United Kingdom. <https://doi.org/10.1093/acprof:oso/9780199295852.001.0001>
- Packard, J. M.** 2003. Wolf behavior: reproductive, social and intelligent. Pages 35–65 *in* *Wolves: Behavior, Ecology and Conservation*. Edited by L. D. Mech and L. Bonam. University of Chicago Press, Chicago, Illinois, USA.
- Packard, J. M.** 2012. Wolf social intelligence. Pages 1–48 *in* *Wolves: Biology, Behavior and Conservation*. Edited by A. P. Maia and H. E. Crussi. Nova Science Publishers, Hauppauge, New York, USA.
- Pavlov, I. P.** 1927. *Conditioned Reflexes*. Dover, New York, New York, USA. <https://doi.org/10.5214/ans.0972-7531.1017309>
- Range, F., and Z. Viranyi.** 2013. Social learning from humans or conspecifics: differences and similarities between wolves and dogs. *Frontiers in Psychology* 4: 868. <https://doi.org/10.3389/fpsyg.2013.00868>
- Skinner, B. F.** 1953. *Science and Human Behavior*. MacMillan, New York, New York, USA.
- Thorndike, E. L.** 1911. Animal intelligence. *American Psychology* 53: 1125–1127.

Received 22 June 2016

Accepted 1 March 2017

Diet and Prey Selection of Barn Swallows (*Hirundo rustica*) at Vancouver International Airport

AUDREY A. LAW^{1,6}, MIRANDA E. THRELFALL^{1,2}, BRENDON A. TIJMAN^{1,3}, ERIC M. ANDERSON¹, SEAN MCCANN⁴, GARY SEARING⁵, and DAVID BRADBEER⁵

¹British Columbia Institute of Technology, 3700 Willingdon Avenue, Burnaby, British Columbia V5G 3H2 Canada

²Current address: 5651 Chester Street, Vancouver, British Columbia V5W 3B3 Canada

³Current address: 8851 Ash Street, Richmond, British Columbia V6Y 3B4 Canada

⁴Simon Fraser University, 8888 University Drive, Burnaby, British Columbia V5A 1S6 Canada

⁵Vancouver International Airport, 3211 Grant McConachie Way, Richmond, British Columbia V7B 0A4 Canada

⁶Corresponding author: audreyalaw@hotmail.com

Law, Audrey A., Miranda E. Threlfall, Brendon A. Tijman, Eric M. Anderson, Sean McCann, Gary Searing, and David Bradbeer. 2017. Diet and prey selection of Barn Swallows (*Hirundo rustica*) at Vancouver International Airport. *Canadian Field-Naturalist* 131(1): 26–31. <https://doi.org/10.22621/cfn.v131i1.1777>

The Barn Swallow (*Hirundo rustica*) is the most widely distributed aerial insectivore in North America, but has declined appreciably in recent decades. Reasons for these declines are largely unknown, though presumably relate mainly to changes in prey availability. To help inform conservation priorities for this species, we assessed their diet and prey selection using birds lethally struck by aircraft at Vancouver International Airport (YVR). Esophagi and gizzards of 31 Barn Swallows collected from June 2013 to October 2013 contained insects mainly from the orders Hymenoptera (mean across birds = 40% of insect numbers), Diptera (31%), Hemiptera (15%), and Coleoptera (12%). To assess prey selection, we compared the esophagi and gizzard contents of 20 swallows collected from July 2013 to September 2013 to populations of aerial insects we sampled during the same period using Malaise traps. Barn Swallows selected strongly for insects in the order Hymenoptera (mainly Formicidae, which comprised 29% of diet), and selected against insects in the orders Coleoptera, Diptera, and Lepidoptera. For all prey taxa combined, Barn Swallows displayed strong selection for insects of length 4–8 mm (body length excluding appendages). Conversely, they selected against smaller and larger insects, despite the fact that smaller insects comprised about 80% of all insects sampled in Malaise traps. Combined with past studies, our results suggest that Barn Swallows select among available aerial insects within local feeding sites for taxa that (i) are of intermediate size, (ii) occur at relatively high density, and (iii) have poor flight performance.

Key Words: Barn Swallow; *Hirundo rustica*; aerial insectivore; diet; prey selection; Vancouver International Airport; British Columbia

Introduction

Populations of aerial insectivores in Canada have declined by 70% since 1970, constituting the most pronounced decline among all categories of Canadian birds (North American Bird Conservation Initiative Canada 2012). The Barn Swallow (*Hirundo rustica*) is the most widely distributed aerial insectivore in North America and has declined appreciably throughout Canada, with Breeding Bird Survey data for 1970–2011 showing a mean annual trend of –4.01% (Environment Canada 2013). Barn Swallows were assessed as *Threatened* in 2011 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), but have yet to be listed under the *Species at Risk Act* (COSEWIC 2011; British Columbia Conservation Data Centre 2013; Government of Canada 2017). The causes of Barn Swallow declines are unknown, but likely include a combination of the following threats on breeding grounds: loss of nesting and foraging sites due to agricultural changes, decreased abundance of aerial insects, climate change, competition for nest sites with House Sparrows (*Passer domesticus*), ectoparasites, and nest removal by humans (COSEWIC 2011).

Very few detailed diet studies have been completed for Barn Swallows, particularly for the North American subspecies (*H. r. erythrogaster*) that differs in behaviour and morphology from the Eurasian subspecies (*H. r. rustica*; Brown and Brown 1999). Limited results for both subspecies suggest that prey size is an important factor affecting prey selection; although small prey items occurred in the diet, Barn Swallows fed mainly on relatively large prey (≥ 1.5 mg dry mass; Turner 1982; Holroyd 1983). Adult Barn Swallows also tend to feed larger prey to their young than they eat themselves (Waugh 1978). A sample of 467 Barn Swallows collected throughout the United States and Canada contained mainly Diptera (39.5%), Hymenoptera (22.7%), Coleoptera (15.6%), and Hemiptera (15.1%; method of analysis not specified; Beal 1918).

The purpose of this study was to assess the diet and prey selection of an at-risk aerial insectivore, the Barn Swallow. To study this sensitive species, we took advantage of birds lethally struck by aircraft at Vancouver International Airport (YVR) on Sea Island in Richmond, British Columbia, Canada (49.2°N, 123.2°W). Barn Swallows are a concern at YVR because since

2000 they have accounted for about 35% of identified birds struck by aircraft annually (D.B., unpublished data). To assess prey selection, we compared the gut contents of Barn Swallows to populations of aerial insects we sampled throughout YVR airfields. These results may help reduce the frequency of Barn Swallow strikes at YVR if the abundance of key prey items can be managed.

Methods

Barn Swallow carcass collection and dissection

We obtained Barn Swallows ($n = 31$) from the YVR airfield after they had been lethally struck by aircraft between 2 June 2013 and 1 October 2013 (specific collection dates were unknown for two swallows obtained during this period). Swallows were not randomly sampled and therefore are not necessarily representative of all Barn Swallows at YVR. Carcasses were collected from the runway < 10 min after they were struck, and then stored at -20°C until they were dissected. For dissections, birds were opened ventrally and the gastrointestinal tract was removed. An incision was made down the entire length of the esophagus and the gizzard and all their contents were flushed and preserved in 95% ethanol until they were processed. The contents of intestines were discarded because digestion rendered them unidentifiable.

Availability of insect prey

We collected samples of insect relative abundance on the YVR airfield from five Malaise traps (156 cm width \times 170 cm height; Figure 1). Malaise traps pro-



FIGURE 1. Locations of sampling sites for the insect prey of Barn Swallows (*Hirundo rustica*) at Vancouver International Airport (YVR). At each of the five sites, Malaise traps were left open from 4 July 2013 to 12 September 2013 during which weekly samples were obtained of insect prey availability ($n = 50$ total samples). Photo: Esri, Redlands, California, USA, 2009.

vide a reliable method of capturing a diverse taxonomic range of flying insects. An exception is Coleoptera that are only captured in Malaise traps at a rate 25% of

that using rotary, glass-barrier, or sticky traps (Juillet 1963; Pickering 1994). Malaise traps were distributed evenly throughout the airfield in areas that would not interfere with airport operations. Malaise traps were left open from 4 July 2013 to 12 September 2013, and samples were gathered weekly from each trap ($n = 50$ total samples). Samples were stored in jars of 95% ethanol at room temperature until they were processed.

Insect identification

Insect specimens from the Malaise traps and from Barn Swallow esophagi and gizzards were identified using dissecting microscopes ($8 \times 32\times$) and taxonomic keys (Triplehorn and Johnson 2005). Specimens in Barn Swallow guts were identified to family, and then further sorted into three size classes: small (0–4 mm body length excluding appendages), medium (4–8 mm), and large (>8 mm). In two cases we sorted insects only to the level of infraorder (Pentatomomorpha, Culicomorpha) and in one case to the level of superfamily (Muscoidea) because many individuals in these groups could not reliably be identified to family. Barn Swallow consumption of many insect families observed in Malaise traps was too low to reliably assess swallow prey selection at the level of family. Thus, prey selection and identification of Malaise trap specimens were conducted only at the level of order. All non-aerial insects, such as spiders, were excluded from Malaise trap samples because Barn Swallows are aerial insectivores. Only one spider was found in the 31 Barn Swallow esophagi and gizzards.

Analysis of Barn Swallow prey selection

We calculated selection ratios separately for insect orders and size classes. However, to avoid biased estimates we did not calculate selection ratios for several orders that were rare (i.e., mean values of $< 1\%$) in either Barn Swallow esophagi and gizzards or Malaise traps. Selection ratios were calculated by dividing the mean percentage of insects that Barn Swallows had consumed by the mean percentage sampled in the Malaise traps (Manly *et al.* 2002). Selection ratios > 1 indicate selection for a prey category, while selection ratios < 1 indicate selection against a prey category. Separately for selection ratios based on insect orders and size classes, we also calculated 95% simultaneous confidence intervals using the Bonferroni inequality as follows:

$$SR \pm [z_{\alpha/(2I)} \times SE(SR)],$$

where SR is a selection ratio, SE is its standard error, z_{α} is the value that is exceeded with probability $\alpha = 0.05$ by a standard normal random variable, and I is the number of selection ratios considered (Manly *et al.* 2002). Collection dates for nine of the 31 Barn Swallows occurred either 32 days before or 6–19 days after the period of Malaise trapping, and exact collection dates for two Barn Swallows were unknown. Thus, for prey selection analysis, we used only the 20 Barn Swallows that were gathered during Malaise trap sampling; col-

lection dates of these Barn Swallows were evenly distributed throughout the period of Malaise trap sampling. Moreover, the relative composition of orders did not vary markedly during the period of Malaise trap sampling: percentages of Diptera and Hemiptera declined slightly, and percentages of Hymenoptera, Lepidoptera, and Psocoptera increased slightly (Figure S1).

Results

Barn Swallow diet

We identified 514 individual insects representing eight orders in the esophagi and gizzards of the 31 Barn Swallows (Table 1). Barn Swallows consumed insects mainly from the orders Hymenoptera (40%), Diptera (31%), Hemiptera (15%), and Coleoptera (12%). The Hymenoptera included mainly Formicidae (ants), the

Diptera included mainly Calliphoridae (blow flies), and the Hemiptera included mainly Pentatomomorpha (seed bugs and stink bugs). The most prevalent of the ants recovered from Barn Swallows were males and queens of *Myrmica specioides* and an unidentified species of *Myrmica*. Of the Hemiptera consumed, most (mean across birds = 78% of insect numbers) belonged to the suborder Heteroptera (true bugs), with a large proportion of these representing a single species of Coreidae, *Ceraleptus pacificus*.

Barn Swallow prey selection

A total of 8608 individual insects representing 12 orders were collected from Malaise traps. We calculated selection ratios for five orders that comprised ≥ 1% of mean values for both Barn Swallow esophagi

TABLE 1. Mean percentages of insect numbers (with 95% CIs) and percent frequency of occurrence (%FO) of insect orders and families identified in esophagi and gizzards of Barn Swallows (*Hirundo rustica*; *n* = 31) collected at YVR after they had been lethally struck by aircraft during 2 June 2013 to 1 October 2013. Results include two infraorders (Culicomorpha, Pentatomomorpha) and one superfamily (Muscoidea) within which many individuals could not reliably be identified to family.

	All Sizes		Small (<4 mm)		Medium (4–8 mm)		Large (>8 mm)	
	Mean % (95% CI)	%FO	Mean % (95% CI)	%FO	Mean % (95% CI)	%FO	Mean % (95% CI)	%FO
Araneae	0.3 (0.6)	3.2	0.3 (0.6)	3.2	—	—	—	—
Coleoptera	12.2 (6.7)	45.2	8.1 (4.5)	38.7	4.1 (4.4)	19.4	0.1 (0.2)	3.2
Cantharidae	0.2 (0.3)	3.2	—	—	0.2 (0.3)	3.2	—	—
Chrysomelidae	1.1 (1.4)	9.7	1.0 (1.4)	6.5	0.1 (0.2)	3.2	—	—
Curculionidae	0.6 (0.9)	6.5	0.6 (0.9)	6.5	—	—	—	—
Elateridae	0.5 (1.1)	3.2	—	—	0.5 (1.1)	3.2	—	—
Staphylinidae	1.9 (3.4)	6.5	—	—	1.8 (3.4)	3.2	0.1 (0.2)	3.2
unidentified spp.	7.9 (5.6)	32.3	6.5 (4.3)	29.0	1.5 (2.8)	6.5	—	—
Diptera	30.5 (13.6)	67.7	11.4 (7.6)	48.4	15.9 (11.7)	35.5	3.2 (6.3)	3.2
Calliphoridae	11.6 (10.6)	22.6	1.2 (2.3)	6.5	7.2 (8.8)	12.9	3.2 (6.3)	3.2
Chloropidae	0.1 (0.1)	3.2	0.1 (0.1)	3.2	—	—	—	—
Culicomorpha	5.4 (6.0)	25.8	5.4 (6.0)	25.8	—	—	—	—
Dolichopodidae	4.3 (3.8)	29.0	4.3 (3.8)	29.0	—	—	—	—
Muscoidea	5.1 (6.1)	12.9	—	—	5.1 (6.1)	12.9	—	—
Psyllidae	0.03 (0.1)	3.2	—	—	0.03 (0.1)	3.2	—	—
Sciomyzidae	3.2 (6.3)	3.2	—	—	3.2 (6.3)	3.2	—	—
Sphaeroceridae	0.2 (0.4)	3.2	—	—	0.2 (0.4)	3.2	—	—
Tipulidae	0.2 (0.3)	6.5	—	—	0.2 (0.3)	6.5	—	—
unidentified spp.	0.4 (0.8)	3.2	0.4 (0.8)	3.2	—	—	—	—
Hemiptera	15.2 (7.4)	51.6	5.9 (5.7)	19.4	9.4 (5.9)	35.5	—	—
Aphididae	3.2 (3.8)	12.9	3.2 (3.8)	12.9	—	—	—	—
Corixidae	0.1 (0.3)	3.2	—	—	0.1 (0.3)	3.2	—	—
Miridae	1.3 (1.7)	9.7	0.4 (0.7)	3.2	1.0 (1.6)	6.5	—	—
Pentatomomorpha	10.5 (7.0)	29.0	2.3 (4.4)	3.2	8.3 (5.9)	25.8	—	—
Hymenoptera	40.0 (13.0)	77.4	6.8 (5.3)	41.9	33.0 (12.8)	61.3	0.2 (0.3)	3.2
Braconidae	0.3 (0.4)	6.5	0.3 (0.4)	6.5	—	—	—	—
Chalcidoidea	0.1 (0.2)	3.2	—	—	0.1 (0.2)	3.2	—	—
Chrysididae	1.0 (1.4)	6.5	0.4 (0.7)	3.2	0.6 (1.3)	3.2	—	—
Formicidae	29.2 (12.3)	51.6	—	—	29.2 (12.3)	51.6	—	—
Halictidae	1.4 (1.3)	12.9	0.6 (0.8)	6.5	0.7 (1.0)	6.5	—	—
Pteromalidae	1.1 (2.1)	3.2	1.1 (2.1)	3.2	—	—	—	—
Tenthredinidae	0.3 (0.5)	6.5	0.1 (0.3)	3.2	0.2 (0.4)	3.2	—	—
unidentified spp.	6.6 (4.2)	51.6	4.4 (3.8)	35.5	2.1 (2.4)	12.9	0.2 (0.3)	3.2
Lepidoptera	0.9 (1.4)	6.5	—	—	—	—	0.9 (1.4)	6.5
Odonata	0.5 (0.8)	6.5	0.1 (0.3)	3.2	—	—	0.4 (0.7)	3.2
Coenagrionidae	0.1 (0.3)	3.2	0.1 (0.3)	3.2	—	—	—	—
unidentified spp.	0.4 (0.7)	3.2	—	—	—	—	0.4 (0.7)	3.2
Thysanoptera	0.4 (0.7)	3.2	0.4 (0.7)	3.2	—	—	—	—

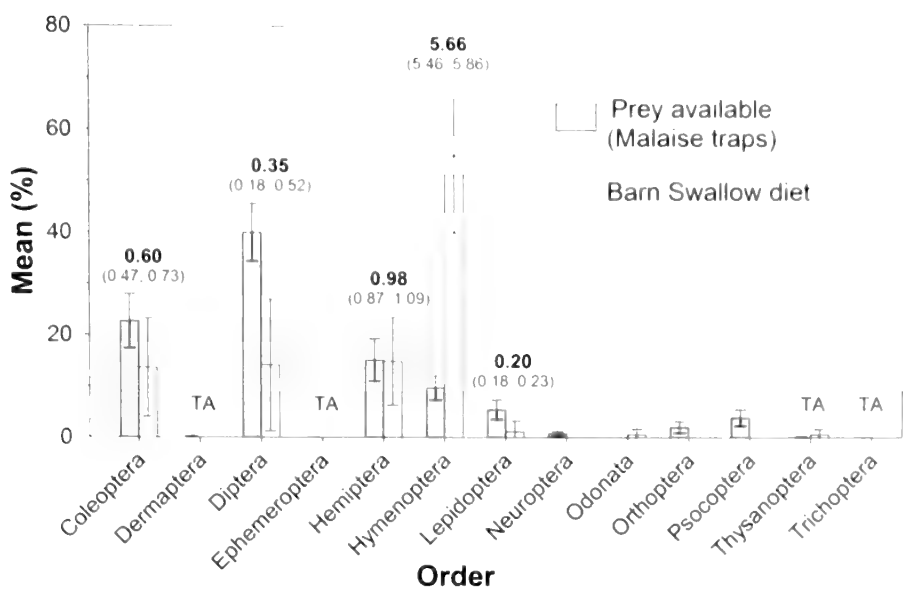


FIGURE 2. Mean percentages of insect numbers (with 95% CIs) for orders (including all size classes) that were sampled in Malaise traps ($n = 50$) or in the esophagi and gizzards of Barn Swallows (*Hirundo rustica*; $n = 20$) that had been struck by aircraft at YVR. Selection ratios with 95% Bonferroni simultaneous CIs are depicted above bars of insect orders for which mean values of prey available and prey consumed by Barn Swallows were both $\geq 1\%$. Malaise traps included all orders except Odonata, but the following orders were not consumed by Barn Swallows: Dermaptera, Ephemeroptera, Neuroptera, Orthoptera, Psocoptera, and Trichoptera. TA (trace available) indicates insects that were present in Malaise trap samples but comprised $< 1\%$. Both available prey and prey consumed by Barn Swallows were sampled from 4 July 2013 to 12 September 2013.

and gizzards and Malaise traps (Figure 2). Of these, Barn Swallows selected for insects in the order Hymenoptera, selected against insects in the orders Coleoptera, Diptera, and Lepidoptera, and showed no preference for or against insects in the order Hemiptera (i.e., the 95% confidence interval for the Hemiptera selection factor included 1). For all prey taxa combined, Barn Swallows displayed selection for insects in the medium size class (4–8 mm; Figure 3). Conversely, they selected against large insects (> 8 mm) and small insects (0–4 mm), despite the fact that small insects comprised about 80% of all insects sampled in Malaise traps.

Discussion

Barn Swallows consumed a wide range of insect taxa at YVR, but over half their diet consisted of just three taxa: Hymenoptera: Formicidae (29%), Diptera: Calliphoridae (12%), and Hemiptera: Pentatomomorpha (11%). Our results are consistent with past studies in both North America and Europe indicating that during the breeding period both Barn Swallow adults and nestlings (via their parents) consume aerial insects mainly in the orders Coleoptera, Hymenoptera, Diptera, and Hemiptera (Beal 1918; Holroyd 1983; Kopij 2000; Turner 2006; Orłowski and Karg 2011, 2013). However, Barn Swallow diets differed appreciably among studies in terms of their relative consumption of insects in these four orders as well as their reliance on insects at finer taxonomic levels. Our results, together with those of past studies, suggest that Barn Swallows

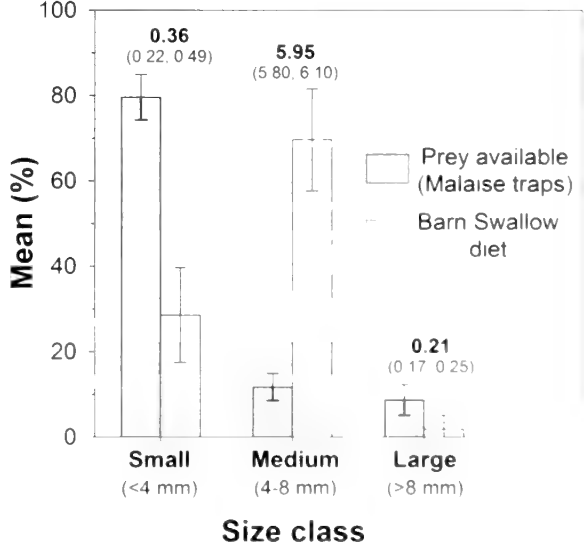


FIGURE 3. Mean percentages of insect numbers (with 95% CIs) for small, medium, and large size classes (all taxa combined, body length excluding appendages) that were sampled in Malaise traps ($n = 50$) and in the esophagi and gizzards of Barn Swallows (*Hirundo rustica*; $n = 20$) that had been struck by aircraft at YVR. Selection ratios with 95% Bonferroni simultaneous CIs are depicted above bars for each size class. Both available prey and prey consumed by Barn Swallows were sampled from 4 July 2013 to 12 September 2013.

do not rely on consistent prey taxa across sites, but instead select among available aerial insects within local feeding sites for taxa of intermediate size, weak flight

performance (i.e., low speed and maneuverability), and that occur at relatively high densities. Formicidae, the most heavily consumed taxa in this study, appear to satisfy these three criteria.

Barn Swallows at YVR selected intermediate sizes of aerial insects (4–8 mm body length) that comprised just over 10% of available prey, while selecting against small insects (<4 mm) that comprised nearly 80% of available prey. Although differences in techniques used to measure insect size restrict direct comparison, past studies similarly indicated that intermediate to large insects are selected by adult Barn Swallows (Turner 1982; Holroyd 1983) and are fed to nestlings (Orłowski and Karg 2011, 2013). For instance, insects > 0.5 mg dry body mass comprised just 14% of available insects, yet constituted 50% of nestling diets in rural Poland (Orłowski and Karg 2011). Compared to small insects, large insects yield greater net energy gains to Barn Swallows despite requiring greater foraging effort (Turner 2006). Thus, selection against Coleoptera and Diptera by YVR Barn Swallows was likely due in part to the mainly smaller sizes of these prey (74% of Coleoptera and 95% of Diptera in Malaise traps were <4 mm). Further, we may have underestimated selection against Coleoptera because Malaise traps may under-sample insects in this order (i.e., Malaise traps may sample only about 25% of the numbers obtained using rotary, glass-barrier, or sticky traps; Juillet 1963). The profitability of insect prey may decline above a body size threshold given that Barn Swallows at YVR selected against the largest insects (>8 mm). Selection against Lepidoptera may have resulted, in part, from the mainly large sizes of insects in this order (62% of Lepidoptera in Malaise traps were >8 mm). The relative benefits of larger prey may decline when smaller prey are highly abundant or are easily captured due to weak flight performance; these two factors appeared to underlie the significant consumption of small-bodied Formicidae and Ichneumonidae by Barn Swallows in several breeding sites in Poland (Orłowski and Karg 2011). The size of prey consumed by breeding Barn Swallows is also positively correlated with the distance between feeding and nesting sites (Waugh 1978; Turner 2006).

The profitability of prey to Barn Swallows also appears to increase with the tendency of prey to aggregate in dense swarms. For instance, the two most heavily consumed families of prey in our study included Formicidae and Calliphoridae, presumably because insects in these families commonly aggregate to mate (Formicidae) or to feed (Calliphoridae; Triplehorn and Johnson 2005). Past studies of Barn Swallow diets also reported significant consumption of Formicidae and Calliphoridae (Beal 1918; Orłowski and Karg 2011). The species most heavily consumed by YVR Barn Swallows was likely *M. specioides* (Formicidae), based on our detailed assessment of 2013 swallows as well as preliminary observation of swallows that were lethally

struck in 2014 (S.M., unpublished data). *Myrmica specioides* is an invasive ant that was first observed in British Columbia in 2011 (R. Higgins, personal communication).

Declines in Barn Swallow populations appear to be due, in part, to reduced abundance of their aerial insect prey resulting from factors such as climate change, wetland loss, light pollution, and agricultural intensification (e.g., loss of pastureland, increased pesticide use; Evans *et al.* 2007; COSEWIC 2011). Formicidae appear to be a relatively unique prey type that increases in urban settings (McIntyre 2000), and managing the distribution or abundance of *Myrmica* ants at YVR may help reduce strikes of Barn Swallows by aircraft. Whether insect management programs at airports succeed in reducing strikes of aerial insectivores will require a thorough knowledge of the life history and ecology of these bird species as well as their insect prey.

Acknowledgements

The YVR Wildlife Management Program was instrumental in collecting Barn Swallow carcasses and insect samples, as well as graciously providing workspace and equipment. Paul Levesque collected the insect samples from the Malaise traps. Rob Higgins, Thompson Rivers University, provided expertise in ant identification on 1 February 2014. Lastly, we thank Tom Saare and the BCIT Renewable Resources Department for lending us additional lab equipment.

Literature Cited

- Beal, F.** 1918. Food habits of the swallows, a family of valuable native birds. Bulletin. United States Department of Agriculture, No. 619. <https://doi.org/10.5962/bhl.title.108596>
- British Columbia Conservation Data Centre.** 2013. Species summary: *Hirundo rustica*. B.C. Ministry of Environment. Accessed 4 September 2015. <http://a100.gov.bc.ca/pub/eswp/speciesSummary.do?id=17978>.
- Brown, C. R., and M. B. Brown.** 1999. Barn Swallow (*Hirundo rustica*). The Birds of North America Online. Edited by A. Poole. Cornell Lab of Ornithology, Ithaca, New York, USA. Accessed 4 September 2015. <https://birdsna.org/Species-Account/bna/species/barswa>.
- COSEWIC (Committee on the Status of Endangered Wildlife in Canada).** 2011. COSEWIC assessment and status report on the Barn Swallow *Hirundo rustica* in Canada. Ottawa. Accessed 4 September 2015. http://www.sararegis.gc.ca/virtual_sara/files/cosewic/sr%5Fbarn%5Fswallow%5F0911%5Feng%2Epdf.
- Environment Canada.** 2013. Trend results for Barn Swallow. North American Breeding Bird Survey – Canadian Trends Website, Data Version 2011. Environment Canada, Gatineau, Quebec. Accessed 4 September 2015. <http://www.ec.gc.ca/ron-bbs/P004/A001/?lang=e&m=s&r=BARS&p=->.
- Evans, K. L., J. D. Wilson, and R. B. Bradbury.** 2007. Effects of crop type and aerial invertebrate abundance on foraging barn swallows *Hirundo rustica*. Agriculture, Ecosystems & Environment 122: 267–273. <https://doi.org/10.1016/j.agee.2007.01.015>

- Government of Canada.** 2017. Species at Risk Public Registry. Species Profile for Barn Swallow. Accessed 26 January 2017. <http://sararegistry.gc.ca/species/speciesDetails.e.cfm?sid=1147#ot18>.
- Holroyd, G. L.** 1983. Foraging strategies and food of a swallow guild. Ph.D. thesis, University of Toronto, Toronto, Ontario, Canada.
- Juillet, J. A.** 1963. A comparison of four types of traps used for capturing flying insects. *Canadian Journal of Zoology* 41: 219–223. <https://doi.org/10.1139/z63-023>
- Kopij, G.** 2000. Diet of swifts (Apodidae) and swallows (Hirundinidae) during the breeding season in South African grassland. *Acta Ornithologica* 35: 203–206. <https://doi.org/10.3161/068.035.0201>
- Manly, B. F. J., L. L. McDonald, D. L. Thomas, T. L. McDonald, and W. P. Erickson.** 2002. Resource Selection by Animals: Statistical Design and Analysis for field Studies. Second edition. Kluwer Academic Publishers, New York, USA. <https://doi.org/10.1007/0-306-48151-0>
- McIntyre, N. E.** 2000. Ecology of urban arthropods: a review and a call to action. *Annals of the Entomological Society of America* 93: 825–835. [https://doi.org/10.1603/0013-8746\(2000\)093\[0825:EOUAAR\]2.0.CO;2](https://doi.org/10.1603/0013-8746(2000)093[0825:EOUAAR]2.0.CO;2)
- North American Bird Conservation Initiative Canada.** 2012. The State of Canada's Birds, 2012. Environment Canada, Ottawa, Canada. Accessed 4 September 2015. www.stateofcanadasbirds.org/State_of_Canada's_birds_2012.pdf.
- Orłowski, G., and J. Karg.** 2011. Diet of nestling Barn Swallows *Hirundo rustica* in rural areas of Poland. *Central European Journal of Biology* 6: 1023–1035. <https://doi.org/10.2478/s11535-011-0070-4>
- Orłowski, G., and J. Karg.** 2013. Partitioning the effects of livestock farming on the diet of an aerial insectivorous passerine, the Barn Swallow *Hirundo rustica*. *Bird Study* 60: 111–123. <https://doi.org/10.1080/00063657.2012.748717>
- Pickering, J.** 1994. Calibration of Malaise traps for studying insect diversity. Discover Life. Accessed 4 September 2015. <http://www.discoverlife.org/pa/or/idp/PROPOSALS.nsf/94.final.html>.
- Triplehorn, C. A., and N. F. Johnson.** 2005. Borror and DeLong's Introduction to the Study of Insects. Seventh edition. Thomson Learning, Inc., Brooks Cole, Belmont, California, USA.
- Turner, A. K.** 1982. Optimal foraging by the swallow (*Hirundo rustica*, L): prey size selection. *Animal Behaviour* 30: 862–872. [https://doi.org/10.1016/S0003-3472\(82\)80160-7](https://doi.org/10.1016/S0003-3472(82)80160-7)
- Turner, A. K.** 2006. The Barn Swallow. T. & A. D. Poyser, London, United Kingdom.
- Waugh, D. R.** 1978. Predation strategies in aerial-feeding birds. Ph.D. thesis, University of Stirling, Stirling, United Kingdom.

Received 23 March 2016

Accepted 26 January 2017

SUPPLEMENTARY MATERIAL:

FIGURE S1. Percentages of insects by order sampled from all five malaise traps during July ($n = 15$ total samples), August ($n = 25$ total samples), and September ($n = 10$ total samples) 2013. Orders with low abundance were grouped in the category 'Other' (orders Dermaptera, Ephemeroptera, Thysanoptera, and Trichoptera).

Evidence for the Historical Occurrence of Wolves (*Canis* spp.) in Nova Scotia, Canada

ANDREI N. WHITAKER^{1, 2} and KAREN F. BEAZLEY^{1, 3}

¹School for Resource and Environmental Studies, Faculty of Management, Dalhousie University, 6100 University Avenue, Halifax, Nova Scotia B3H 4R2 Canada

²Current address: Johns Southward Glazier Walton & Margetts L.L.P., #204–655 Tyee Road, Victoria, British Columbia V9A 6X5 Canada

³Corresponding author: karen.beazley@dal.ca

Whitaker, Andrei N., and Karen F. Beazley. 2017. Evidence for the historical occurrence of wolves (*Canis* spp.) in Nova Scotia, Canada. *Canadian Field-Naturalist* 131(1): 32–36. <https://doi.org/10.22621/cfn.v131i1.1775>

Although once common across the entire North American continent, wolves (*Canis* spp.) have been extirpated from most of their former territory. The historical occurrence and persistence of wolves in Nova Scotia has been a subject of debate because of comments on the wolf's rarity in early settler accounts and the absence of physical specimens. By consulting historical documents of European settlers, the Mi'kmaw lexicon, and fur trade records, we found evidence for the presence of a wolf population in Nova Scotia (which included the territory of New Brunswick before 1784) at European contact and persisting until the early 20th century.

Key Words: Historical distribution; wolves; *Canis lycaon*; *Canis lupus*; anecdotal evidence; Maritime Provinces

Introduction

The story of the wolf (*Canis* spp.) in North America is inextricably linked to the story of European colonization. As settlers displaced and replaced wild ungulates and other prey, wolves turned to the herds of colonial livestock as a food source (McIntyre 1995; Steinhart 1996). As colonists relied heavily on their stock for survival, they implemented a bounty system to try to eliminate the wolf from areas surrounding their settlements (McIntyre 1995; Steinhart 1996; Robinson 2001). The bounties, coupled with overall habitat degradation from human expansion and resource development, caused the wolf to be eradicated from roughly half its range, including the Canadian Maritime Provinces, by the middle of the 20th century (Carbyn 1987). It is believed wolves were eliminated from the Maritime Provinces sometime within the last quarter of the 19th century (Smith 1940; Carbyn 1987; Hayes and Gunson 1995; Lohr and Ballard 1996), although estimates of the timing vary from the mid-1860s (Gilpin 1867; Ganong 1908) to the early 20th century (Sheldon 1936).

The taxonomy of wolves in eastern North America is controversial. The wolf species that inhabited eastern Canada and the northeastern United States is generally known as the Eastern Wolf or the Eastern Timber Wolf (*Canis lycaon*) and also as the subspecies *C. lupus lycaon* (Nowak 1983, 1995; Rutledge *et al.* 2012). However, it is difficult to conclude whether *C. lycaon*, *C. lupus*, or subspecies of the latter inhabited the region because of the absence of physical specimens. Although it is certain that past canids were not Coyotes (*C. latrans*), which were not resident in the Maritime Provinces until the 1960s (Forbes *et al.* 2010), the taxonomic identity of the wolf that historically occurred in Nova Scotia is unclear.

While wolves were historically documented in the region, some authors have questioned whether the Maritimes supported a self-sustaining population (Ganong 1908; Lohr and Ballard 1996); based on comments in early settler accounts on the wolf's rarity, some have even doubted the existence of a resident wolf population in Nova Scotia altogether (Dodds *et al.* n.d.). In this study, we investigated European settler accounts, Mi'kmaw evidence, and fur trade records to determine the grounds for a historical Nova Scotian wolf population.

Methods

We conducted a literature search to find evidence of wolves in historical documents pertaining to Nova Scotia (Figure 1), which, until 1784, included the territory that became New Brunswick. As Nova Scotia was occupied by the Mi'kmaq, French, and English, there are historical accounts in all three languages; however, only original English documents and those translated into English were consulted. This limitation poses the risk of excluding important Mi'kmaw and French sources and is, thus, likely to result in a conservative account of wolf presence. In addition to the literature search, we also examined trapping statistics from the Dominion Bureau of Statistics (now Statistics Canada) and fur trade reports from the United Kingdom and the French settlement of Louisbourg (an important shipping port on Cape Breton Island, Nova Scotia, during the period of French occupation and rule).

Results and Discussion

Evidence from the Mi'kmaq

The earliest evidence for the existence of wolves in Nova Scotia is found in the folklore and cultural history

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalists' Club.

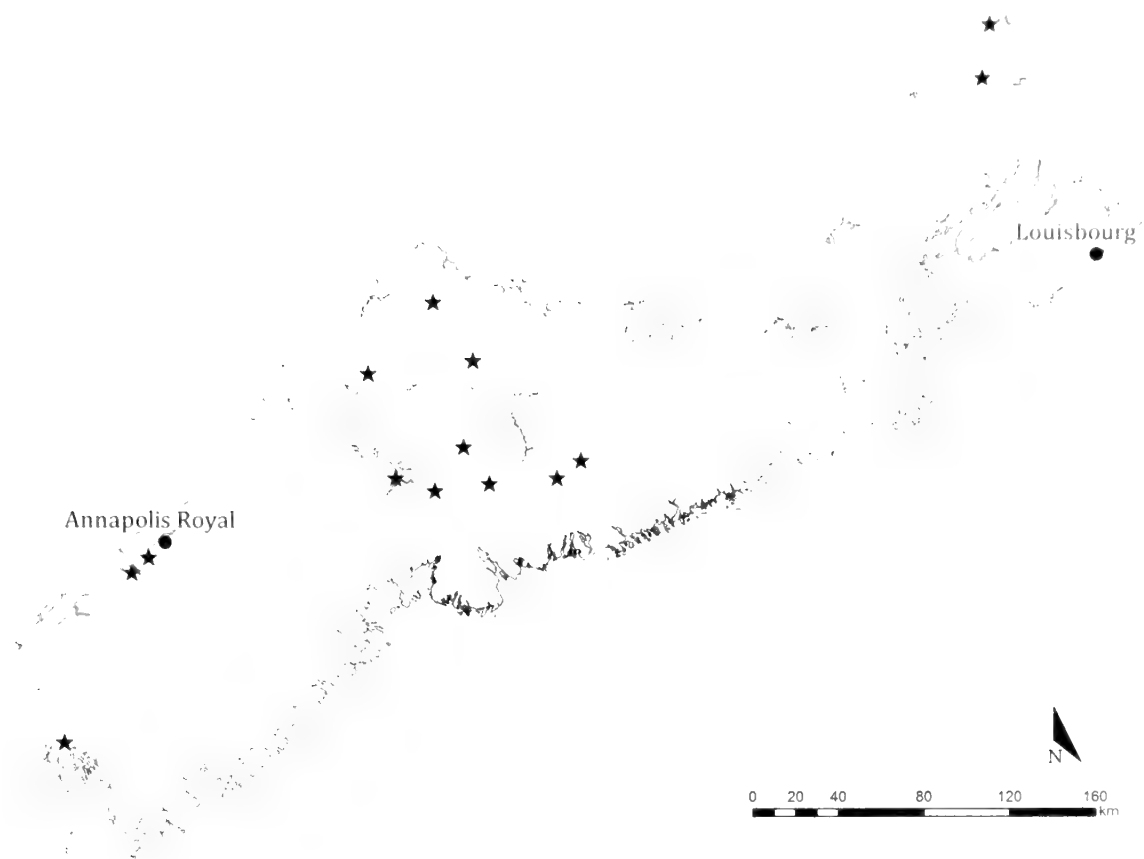


FIGURE 1. Historical occurrences of wolves (stars) in the area of the present-day province of Nova Scotia, as recorded in literary sources, 1606–1905.

of the Mi'kmaq. Archaeological digs at pre-contact Mi'kmaw sites in eastern Nova Scotia have yielded wolf remains (Ricker 1997). The early Mi'kmaw lexicographer, Reverend Silas T. Rand, gives the Mi'kmaw word for wolf as “böktūsūm” (Rand 1875, 1888) and notes that the language had an adjective, “böktūsū-mooa”, for describing someone or something as wolfish (Rand 1888). The wolf is also present in Mi'kmaw legends, often portrayed as a companion to the guardian Gluskap (Hardy 1855a; Rand 1894; Wallis and Wallis 1995).

Evidence from Settlers

The wolf is mentioned in writings from the beginning of French settlement in what is now Nova Scotia, in the Port Royal/Annapolis Royal region (Lescarbot 1609, 1914). In 1609, Lescarbot described wolves as being present in the region and noted that a neighbouring chief's name carried the meaning of wolf (Lescarbot 1914). When describing the food habits of the native population, he observed “[a]s for beafts of the woods they eat all of them, the woolfe excepted [sic]” (Lescarbot 1609: 212) and stated “I will not ftand to fpeake of woolues (for they haue fome, and yet eat none of them) [sic]” (Lescarbot 1609: 255). Soon after the French settled at Port Royal (now Annapolis Royal),

Jesuit missionaries were sent to New France (now Nova Scotia). In a letter of 1612, Father Biard made reference to the occurrence of the wolves around Port Royal while remarking upon the language gap between the Europeans and the local Mi'kmaq, writing, “They will name to you a wolf, a fox, a squirrel, a moose, and so on to every kind of animal they have” (Biard 1896: 11).

In 1794, the concern over wolves harassing sheep was great enough for a bill to be passed in the provincial legislature promoting their elimination (Table 1; 34 Geo III c II). Then, two years later, another Act was passed to encourage the destruction of wolves and other predators in response to damages they had wrought (Table 1; 36 Geo III c XVII). This Act was resurrected again in 1801 because of the continuing harm these animals were causing to livestock in Nova Scotia (Table 1; 41 Geo III c VII).

Sir George Head (1829: 42) reported that in Nova Scotia “wolves... are in sufficient numbers through all parts of the forests”. Gesner (1847, 1849) writes that in the mid-1840s wolves were seen near Halifax and captured in the neighbourhoods of Windsor and Musquodboit. At roughly the same time, Gilpin (1867: 12) observed that wolves were “in every part of the province... from north to the extreme south”. In 1845, wolf

TABLE 1. Nova Scotia legislation promoting wolf bounties, 1794–1851.

Year	Duration	Title of Statute
1794	None stated	<i>An Act for the preservation of Sheep</i> , S.N.S. 1794 (34 Geo III), c II
1796	July 1 1797	<i>An Act to encourage the killing of Wolves, Bears, Loup Cerviers, and Wild Cats</i> , S.N.S. 1796 (36 Geo III), c XVII
1801	Three years	<i>An Act to revive, and continue, an Act made in the thirty-sixth year of his Majesty's reign, entitled, An Act to encourage the killing of Wolves, Bears, Loup Cerviers, and Wild Cats</i> , S.N.S. 1801 (41 Geo III), c VII
1845	None stated	<i>An Act to encourage the Killing of Wolves</i> , S.N.S. 1845 (8 Vic), c XLVII
1846	None stated	<i>An Act to amend the Act to encourage the Killing of Wolves</i> , S.N.S. 1846 (9 Vic), c XVII
1851	Repealed by 1884	<i>Of The Destruction of Noxious Animals</i> , R.S.N.S. 1951 (14 Vic), c 93

bounties were revived by the province after a 40 year absence (Table 1; 8 Vic c XLVII) and continued to the latter years of the century. In 1885, the authority for granting wolf bounties was transferred from the province to the municipalities (*An Act to amend Chapter 56 of the Revised Statutes, Fifth Series, "Of County Incorporations"*, S.N.S. 1885 c 13).

Evidence from Fur Trade Records

Trade in wolf skins is first mentioned in the sparse importation accounts, present only from a few years in the early 1740s, of the French colony of Louisburg on Cape Breton Island. Between 1740 and 1743, 22 wolf pelts were brought into Louisburg from Nova Scotia (Gwyn 2003). As this number reflects only pelts brought to Louisburg on trading ships, it is likely that the number of wolf skins traded at the fort during this period was higher (K. Donovan, personal communication, 2006). In addition, the account books from suppliers Simonds and White from the area surrounding the Saint John River, New Brunswick, also list “two Nova

Scotia wolf” among the furs traded southward from 1764 to 1774 (Raymond 1943: 158).

The Nova Scotia fur trade also extended across the Atlantic to the United Kingdom. The London Custom House records show that the first wolf pelt from Nova Scotia was exported in 1753. From this year onward, wolf skins were steadily exported until 1867, the last year they are recorded. All in all, 1368 wolf skins were sent to England from Nova Scotia, for an average of 12 a year over 114 years (Table 2). Of these, only 10 wolf skins were exported during the period when New Brunswick was part of Nova Scotia (until 1784).

The final mention of the wolf is in the annual reports that the Dominion Bureau of Statistics began to publish after 1919. A total of 18 wolves were reported to be trapped in Nova Scotia in the 1919–20 season, and a further 10 wolves were harvested in 1920–21 (Novak *et al.* 1987). No more wolves were trapped until the 1927–28 season, when a single wolf was collected; after this, no further wolves are reported from Nova Scotia (Novak *et al.* 1987).

TABLE 2. Records of wolf pelts exported from Nova Scotia and Cape Breton to the United Kingdom, 1745–1870.*

Year	No. pelts	Year	No. pelts	Year	No. pelts
1753	2	1801	2	1846	4
1754	2	1805	29	1847	52
1763	1	1809	3	1848	23
1777	1	1816	24	1851	2
1782	4	1817	80	1852	2
1785	1	1818	1	1853	2
1787	1	1819	66	1854	2
1789	2	1820	1	1855	23
1790	1	1822	344	1856	15
1791	1	1830	1	1859	200
1792	1	1831	13	1862	1
1793	5	1834	1	1863	89
1794	1	1837	2	1864	83
1795	1	1838	3	1865	20
1797	4	1840	6	1866	124
1800	1	1844	1	1867	120

Source: Inspector-General's Ledgers of Imports and Exports housed in the National Archives, Kew, England. Information retrieved by Dr. Julian Gwyn. In chronological order, the ledgers consulted were: CUST3/53, 3/54, 3/63, 3/77, 17/7, 17/8, 17/9, 17/10, 17/11, 17/12, 17/13, 17/14, 17/15, 17/16, 17/18, 17/22, 17/26, 17/30, 5/4, 5/5, 5/6, 5/7, 5/8, 5/10, 5/19, 5/20, 5/23, 5/26, 5/27, 5/29, 5/33, 5/35, 5/37, 5/39, 5/45, 5/47, 5/49, 5/51, 5/53, 5/61, 5/67, 5/69, 5/73, 5/77, 5/83, 5/89.

*1813 data are missing as the London Custom House burned down that year and no trade data survived. Between 1757 and 1761, there were no fur exports from Nova Scotia to England. Until 1784, data may include furs from the territory that became New Brunswick.

Conclusion

Although early naturalists observed that wolves were found across the entire North American continent, a few 19th century writers believed that the wolf was not a resident species in the Canadian Maritimes region (Lohr and Ballard 1996). Gesner (1847) and Levinge (1846) claimed that wolves first entered New Brunswick in the 1800s in pursuit of White-tailed Deer (*Odocoileus virginianus*), and Gesner (1849) claimed that the wolf was not part of the “native” fauna of Nova Scotia. Hardy (1855b: 51) echoed this viewpoint when he noted that the wolf had “but lately made his appearance in Nova Scotia”, as did Duvar (1867: 63) when he wrote that wolves in Nova Scotia were “rare visitor[s] from the adjoining province of New Brunswick”.

The belief that wolves migrated into the province during the 19th century may have been related to a probable increase in wolf-human interactions that occurred in the same period. The human population of Nova Scotia rose from 12 000 in 1781 to 350 000 in 1867 (Gesner 1849), which may have decreased the available habitat and prey populations for wolves, while increasing the likelihood of wolf observations through human expansion into former wolf territory. Our investigation shows that not only was the wolf present in Nova Scotia during the beginning of European settlement, but also that the animal was not extirpated until the 1920s. Although the evidence cannot tell us an overall population size, it does show that a persistent population of wolves did exist in Nova Scotia until the first quarter of the 20th century.

Acknowledgements

We thank J. Gwyn for information pertaining to the historical trade of wolf pelts from Nova Scotia and for generously providing personally retrieved data from England on Nova Scotia’s fur trade with the United Kingdom. We also thank K. Donovan (Fortress of Louisbourg National Historic Site) for sharing his knowledge of 18th century fur trade at Louisburg. S. Toni contributed to the editing of this paper. Finally, we thank D. McAlpine, B. Patterson, and G. Forbes for guidance on wolf nomenclature.

Literature Cited

- Biard, P.** 1896. Letter from Father Pierre Biard to the Reverend Father Provincial, at Paris: Port Royal, January 31, 1612. Pages 5–56 in *Jesuit Relations and Allied Documents: Travels and Explorations of the Jesuit Missionaries in New France, 1610–1792*. Volume II: Acadia: 1612–1614. Edited by R. G. Thwaites. Burrows Brothers, Cleveland, Ohio, USA.
- Carbyn, L. N.** 1987. Gray wolf and red wolf. Pages 358–377 in *Wild Furbearer Management and Conservation in North America*. Edited by M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch. Ontario Ministry of Natural Resources, and Ontario Trappers’ Association, Toronto, Ontario, Canada.
- Dodds, D. F., E. Mullen, and A. Martell.** n.d. Notes on rare and extinct carnivora of Nova Scotia. Unpublished paper. Nova Scotia Department of Lands and Forests, Kentville, Nova Scotia, Canada.
- Duvar, J. H.** 1867. Some additions to the game of Nova Scotia. *Proceedings and Transactions of the Nova Scotia Institute of Natural Science* 1: 59–69. <http://hdl.handle.net/10222/10117>
- Forbes, G. J., D. F. McAlpine, and F. W. Scott.** 2010. Mammals of the Atlantic Maritime Ecozone. Pages 693–718 in *Assessment of Species Diversity in the Atlantic Maritime Ecozone*. Edited by D. F. McAlpine and I. M. Smith. NRC Research Press, Ottawa, Ontario, Canada.
- Ganong, W. F.** 1908. On the occurrence of the wolf in New Brunswick. *Bulletin of the Natural History Society of New Brunswick* 26: 30–35.
- Gesner, A.** 1847. New Brunswick: with Notes for Emigrants, Comprehending the Early History, an Account of the Indians, Settlement, Topography, Statistics, Commerce, Timber, Manufactures, Agriculture, Fisheries, Geology, Natural History, Social and Political State, Immigrants, and Contemplated Railways of that Province. Simmonds & Ward, London, United Kingdom. <https://catalog.hathitrust.org/Record/001971671>
- Gesner, A.** 1849. The Industrial Resources of Nova Scotia: Comprehending the Physical Geography, Topography, Geology, Agriculture, Fisheries, Mines, Forests, Wild Lands, Lumbering, Manufactories, Navigation, Commerce, Emigration, Improvements, Industry, Contemplated Railways, Natural History and Resources of the Province. A & W MacKinlay, Halifax, Nova Scotia, Canada. <https://catalog.hathitrust.org/Record/011614494>
- Gilpin, J. B.** 1867. On the mammalia of Nova Scotia, no. II. *Proceedings and Transactions of the Nova Scotian Institute of Natural Science* 1: 8–15.
- Gwyn, J.** 2003. The Mi’kmaq, poor settlers, and the Nova Scotian fur trade, 1783–1853. *Journal of the Canadian Historical Association* 14: 65–91. <https://doi.org/10.7202/010320ar>
- Hardy, C.** 1855a. Sporting Adventures in the New World, or, Days and Nights of Moose-Hunting in the Pine Forests of Acadia, Volume II. Hurst and Blackett, London, United Kingdom. <https://catalog.hathitrust.org/Record/008628210>
- Hardy, C.** 1855b. Sporting Adventures in the New World, or, Days and Nights of Moose-Hunting in the Pine Forests of Acadia, Volume I. Hurst and Blackett, London, United Kingdom. <https://catalog.hathitrust.org/Record/008628210>
- Hayes, R. D., and J. R. Gunson.** 1995. Status and management of wolves in Canada. Pages 21–33 in *Ecology and Conservation of Wolves in a Changing World*. Edited by L. N. Carbyn, S. H. Fritts, and D. R. Seip. Occasional publication 35. Canadian Circumpolar Institute, Edmonton, Alberta, Canada.
- Head, G.** 1829. Forest Scenes and Incidents in the Wilds of North America: Being a Diary of a Winter’s Route from Halifax to the Canadas, and During Four Months’ Residence in the Woods on the Borders of Lakes Huron and Simcoe. John Murray, London, United Kingdom.
- Lescarbot, M.** 1609. Nova Francia: or the Description of that Part of New France, which is One Continent with Virginia. Translated by P. Erondelle. George Bishop, London, United Kingdom.
- Lescarbot, M.** 1914. The History of New France, Volume III. Translated by W. L. Grant. Champlain Society, Toronto, Ontario, Canada. <https://doi.org/10.3138/9781442617865>
- Levinge, R. G. A.** 1846. Echoes from the Backwoods: or Sketches of Transatlantic Life, Volume I. Henry Colburn,

- London, United Kingdom. <https://doi.org/10.1017/cbo9781139060387>
- Lohr, C., and W. B. Ballard.** 1996. Historical occurrence of wolves, *Canis lupus*, in the Maritime Provinces. *Canadian Field-Naturalist* 110: 607–610.
- McIntyre, R.** 1995. Hunting their lost tribe. Pages 15–28 in *War against the Wolf: American's Campaign to Exterminate the Wolf*. Edited by R. McIntyre. Voyageur Press, Stillwater, Minnesota, USA.
- Novak, M., M. E. Obbard, J. G. Jones, R. Newman, A. Booth, A. J. Satterthwaite, and G. Linscombe.** 1987. Furbearer harvests in North America, 1600–1984. Pages 267–270 in *Wild Furbearer Management and Conservation in North America*. Edited by M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch. Ontario Ministry of Natural Resources and Ontario Trappers' Association, Toronto, Ontario, Canada.
- Nowak, R. M.** 1983. A perspective on the taxonomy of wolves in North America. Pages 10–19 in *Wolves in Canada and Alaska: Their Status, Biology, and Management*. Edited by L. N. Carbyn. Canadian Wildlife Service report series 45. Environment Canada, Ottawa, Ontario, Canada.
- Nowak, R. M.** 1995. Another look at wolf taxonomy. Pages 375–398 in *Ecology and Conservation of Wolves in a Changing World*. Edited by L. N. Carbyn, S. H. Fritts, and D. R. Seip. Occasional publication 35. Canadian Circumpolar Institution, Edmonton, Alberta, Canada.
- Rand, S. T.** 1875. *A First Reading Book in the Micmac Language: Comprising the Micmac Numerals, and the Names of the Different Kinds of Beasts, Birds, Fishes, Trees, &c. of the Maritime Provinces of Canada*. Nova Scotia Printing Company, Halifax, Nova Scotia, Canada.
- Rand, S. T.** 1888. *Dictionary of the Language of the Micmac Indians, Who Reside in Nova Scotia, New Brunswick, Prince Edward Islands, Cape Breton, and Newfoundland*. Nova Scotia Printing Company, Halifax, Nova Scotia, Canada.
- Rand, S. T.** 1894. *Legends of the Micmacs*. Longmans, Green, and Company. New York, New York, USA.
- Raymond, Rev W. O.** 1943. *The River St. John: Its Physical Features, Legends and History from 1604 to 1784*. Tribune Press, Sackville, New Brunswick, Canada.
- Ricker, D. A.** 1997. *L'stitkuk: the Story of the Bear River Mi'kmaw Community*. Roseway Publishing, Lockeport, Nova Scotia, Canada.
- Robinson, N. A.** 2001. Tracking a new relationship: the wolf in New York law. Pages 97–107 in *Wolves and Human Communities: Biology, Politics, and Ethics*. Edited by V. A. Sharpe, B. G. Norton, and S. Donnelly. Island Press, Washington, DC, USA.
- Rutledge, L. Y., P. J. Wilson, C. F. C. Klütsch, B. R. Patterson, and B. N. White.** 2012. Conservation genomics in perspective: a holistic approach to understanding *Canis* evolution in North America. *Biological Conservation* 155: 186–192. <https://doi.org/10.1016/j.biocon.2012.05.017>
- Sheldon, C.** 1936. The mammals of Lake Kedgemakooog and vicinity, Nova Scotia. *Journal of Mammology* 17: 207–215. <https://doi.org/10.2307/1374415>
- Smith, R. W.** 1940. The land mammals of Nova Scotia. *American Midland Naturalist* 24: 213–241. <https://doi.org/10.2307/2421063>
- Steinhart, P.** 1996. *The Company of Wolves*. Alfred Knopf, New York, New York, USA.
- Wallis, W. D., and W. R. Wallis.** 1955. *The Micmac Indians of Eastern Canada*. University of Minnesota, Minneapolis, Minnesota, USA.

Received 8 February 2016

Accepted 30 January 2017

Edge-habitat Use by Northwestern Gartersnakes (*Thamnophis ordinoides*) in Saanich, British Columbia

GRAHAM P. DIXON-MACCALLUM^{1,2}, KATIE A. H. BELL¹, and PATRICK T. GREGORY¹

¹Department of Biology, P.O. Box 3020, University of Victoria, Victoria, British Columbia V8W 3N5 Canada

²Corresponding author: grahamdm@uvic.ca

Dixon-MacCallum, Graham P., Katie A.H. Bell, and Patrick T. Gregory. 2017. Edge-habitat use by Northwestern Gartersnakes (*Thamnophis ordinoides*) in Saanich, British Columbia. *Canadian Field-Naturalist* 131(1): 37–45. <https://doi.org/10.22621/cfn.v131i1.1751>

Understanding habitat requirements of species is fundamental for their conservation and urban parks can provide key habitat for species in otherwise disturbed settings. Northwestern Gartersnakes (*Thamnophis ordinoides*) are common in parks in Saanich, British Columbia, but their specific habitat requirements are poorly understood. Based on previous studies and thermoregulatory needs of snakes, we predicted that edges, particularly field margins, would be heavily used by active snakes. We therefore used surveys that focused on edges to find snakes and measured edge-habitat use by comparing habitat variables at locations where snakes were found to the same variables at nearby random locations. Habitat variables included composition and structure of vegetation, substrate temperature, aspect, and slope. Overall, litter depth, canopy cover, a lack of bare ground and woody vegetation were the most important habitat variables for determining where snakes were found. Our results provide a preliminary assessment to improve our understanding of habitat use for this species. The abundance of snakes found while surveying edges supports our initial assumption that edges are important habitat features but more work is required using multiple survey methods to further test this hypothesis.

Key Words: Northwestern Gartersnake; *Thamnophis ordinoides*; urban wildlife; reptiles; transect surveys; matched-pairs logistic regression; British Columbia

Introduction

City parks and green spaces provide refuge for species that would otherwise be absent in urban areas (Molloy 2011). Plants and animals that reside in parks face challenges that are absent or diminished for their counterparts in more pristine settings (Germaine and Wakeling 2001). In particular, urban parks often have high levels of disturbance from humans who use these parks for recreation. Despite such challenges, parks and green spaces can provide habitat features that allow a wide diversity of species to survive (Germaine and Wakeling 2001; Helden and Leather 2004; Pattishall and Cundall 2009). Studying wildlife in urban and suburban areas is important to inform park managers and city planners of the need to maintain diversity within cities and reduce human-wildlife conflict (DeStefano and DeGraaf 2003). To those ends, studies of the effects of urbanization on wildlife and of habitat use by wildlife within urban centres are useful (Soulé 1991).

Habitat use and habitat selection are both associated with the distribution of a given species (Thomas and Taylor 2006; Johnson 2007). They are related, but differ in that habitat selection is the process by which organisms establish patterns of habitat use (Reinert 1993). Studies describing patterns of habitat use are of interest both in their own right and as a first step for developing studies of habitat selection (Bastille-Rousseau *et al.* 2010). Broad qualitative descriptions of the habitats in which a species is found are useful starting points, but

quantitative studies of habitat use are necessary for real utility to managers and ecologists.

Habitat structure appears to be more important than plant species composition in determining habitat use of snakes. For example, two populations of Timber Rattlesnakes (*Crotalus horridus*) occupied sites with little overlap in plant species composition, but nearly identical vegetative structure in terms of canopy cover and understory vegetation (Reinert 1993). Also, basking sites are of particular importance to reptiles as their digestive rate, speed of movement, foraging efficiency, and reproductive success are all dependent on achieving optimal body temperature (Stevenson *et al.* 1985; Madsen 1987; Lutterschmidt and Reinert 1990; Elzer *et al.* 2013).

Many species of snakes use edge habitats preferentially for diverse purposes (Blouin-Demers and Weatherhead 2001a; Row and Blouin-Demers 2006). In Grasssnakes, *Natrix natrix*, which are related to gartersnakes, individuals select habitat edges presumably to facilitate thermoregulation in close proximity to retreat sites (Wisler *et al.* 2008; Reading and Joffré 2009). In particular, gravid female snakes spend much of their time in areas of high thermal quality close to cover, such as fields, rocky outcrops, and open areas (Huey *et al.* 1989; Charland and Gregory 1995; Row and Blouin-Demers 2006). Because of the importance of structural habitat features such as open basking sites, habitat edges, and canopy cover for thermoregulation and predator avoidance, we focus on quantifying habitat structure

rather than identifying the species of plants that help make up that structure. Although such use of edges has not been tested for Northwestern Gartersnakes (*Thamnophis ordinoides* Baird and Girard 1852), much anecdotal evidence associates them with edges (Stewart 1968; Gregory 1984; Stebbins 2003). We therefore anticipated that edges would be commonly frequented by this species. In this study, we first used random surveys to determine that snakes were most easily detected in edge habitats and then restricted our further searches to edges so that we could determine the key features that distinguish these habitats from random points. We also restricted our analysis to active snakes (i.e., those detected in the open).

The objective of this study was to quantify the structural habitat features of edges used by active Northwestern Gartersnakes at parks in Saanich, British Columbia. To establish that an animal uses habitat non-randomly, the characteristics of locations where it has been found are compared to the characteristics of locations that are available to that animal but are not known to be used (Thomas and Taylor 2006; Johnson 2007). Following this approach, we tested for differences between locations where we found snakes and randomly chosen, nearby locations. We also compared patterns of habitat use for snakes of different sizes, reproductive condition, and digestive state, all factors previously shown to affect habitat use in snakes (Blouin-Demers and Weatherhead 2001a,b; Blouin-Demers *et al.* 2007).

Ideally, to study habitat use, we would use radio-telemetry to track snakes that would enable us to determine where snakes are even when they are hidden from view (Reinert and Cundall 1982; Weatherhead *et al.* 2012). Unfortunately, Northwestern Gartersnakes are relatively small snakes and not very suitable for radio-telemetric studies. However, they are abundant and often active in the open, where they can be readily seen and captured. Although we checked natural cover objects for snakes, we found virtually no snakes under cover. Despite the well-known utility of artificial cover objects in sampling snakes in many situations (Halliday and Blouin-Demers 2015), we did not use artificial cover objects in this study because we have not found them particularly effective in our previous work and because of problems associated with using them in public areas. Furthermore, it is arguable that factors determining habitat use by active snakes and by those seeking cover are separate issues (or at least only partially overlapping). Snakes use cover non-randomly and particular features of cover objects seem to be important in determining their use by snakes. Thus, this study addresses only one small element of the complexities of habitat use by Northwestern Gartersnakes by determining patterns of habitat use of active snakes only. Also, visual encounter surveys of active snakes are limited in that we can only sample snakes that we are able to detect and capture. The results therefore comprise a working hypothesis for future study using appropriate long-term tracking technology when it becomes available.

Study Area

Saanich, British Columbia (48.459°N, 123.377°W) sits at the southern end of Vancouver Island, on the northern edge of Victoria, and these two cities form a continuous urban area. We conducted this study at three parks, Mount Douglas, Mount Tolmie, and Layritz, and two nature sanctuaries, Christmas Hill and Swan Lake. These sites vary in habitat composition from mature Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco var. *menziesii*) forest, Garry Oak (*Quercus garryana* Douglas ex Hooker var. *garryana*) woodland, fields, shrub-land, gravel trails, to roads and sports fields.

Methods

We conducted surveys from May to September 2012. We alternated visiting each site to spend an equal number of days surveying each and to survey evenly across the field season. We focused our surveys between 1000 h and 1600 h and all surveys were conducted by the same two observers, walking at a consistent pace, with one in front of the other. We also searched under every cover object encountered within 1 m either side of the survey route. Beginning in May, we conducted surveys along transects that were randomly determined in the field by spinning the bezel of a compass. Beginning in June, we incorporated habitat edges into snake surveys to increase the number of snake encounters. We chose three vegetation height classes, 0 – 10 cm, 10 – 60 cm, and >60 cm. We considered any boundary between two patches of vegetation of these classes to be an edge. Canopy cover, from trees or tall shrubs, could also form edges, resulting in six vegetation classes (each of the three height classes, with or without canopy cover). Edge surveys consisted of two observers walking at a consistent pace along the boundary between these two vegetation height classes. The boundaries between these vegetation height classes were created by vegetation management (e.g., mowing) and/or occurred naturally (e.g., around patches of bedrock).

We began surveys by rolling an eight-sided die to determine the number of paces to walk into a site. Once we had reached the end of a given number of paces we spun the bezel of a compass to select a random transect to follow. When we reached an edge between two vegetation height classes we ended that transect and began to survey the edge. If the edge was formed around a closed patch of vegetation the original transect was resumed once the whole edge had been followed and we had returned to the location where we had begun the edge survey. For each edge survey we recorded the type of edge we were searching, and the time in minutes that we spent searching it. In some instances, an edge did not reconnect to the location where we ended the transect. This usually occurred because of a physical obstacle, such as a cliff or very dense thorny shrubs. On other occasions, an edge that was initially distinct became impossible to follow because the vegetation became patchy and of inconsistent heights. In either case, when

we could no longer follow an edge, we spun the bezel of a compass to determine the direction of a new random transect. Therefore, each individual survey, a combination of transects and edge searches, was of indeterminate length. We ensured consistent search effort by always walking at a consistent pace and spending an equal number of days searching each site.

We captured snakes by hand, and for each we measured snout-vent-length (SVL), determined sex by probing for hemipenes (or by gently everting hemipenes in young males), gently palpated the stomach to determine if the snake had fed recently, and palpated the abdomen of mature females to determine reproductive status (pregnant or not). Finally, we marked each snake with a passive-integrated transponder (PIT) tag (Avid encrypted 125 kHz, Avid Identification Systems, Norco, California, USA) to avoid including recaptures in statistical analyses and thereby generating pseudoreplication (Hurlbert 1984).

We quantified the habitat surrounding capture locations, as well as a random paired location nearby, using 13 habitat characteristics (Table 1) that are of potential relevance to snakes (Reinert 1993; Blouin-Demers and Weatherhead 2001a; Wisler *et al.* 2008). Habitat variables were measured at capture locations immediately after each snake was captured. Habitat variables were measured at paired locations immediately after completion of the measurements at capture locations, typically within 20 min.

To determine the centre point for each paired-random plot we rolled an eight-sided die to select a compass bearing: 1 = North, 2 = Northeast, 3 = East, etc. and then walked about 50 m in that direction (measured by pacing). We chose 50 m as a distance that is within the potential movement range of an individual Northwestern Gartersnake in a day (Lawson 1991), but large enough to capture habitat heterogeneity. To determine the middle point for the paired plot we walked 50 m and placed a marker along the compass line. At each

paired point we repeated all measurements taken at the capture point.

In some instances we encountered snakes but were unable to capture them. If we were certain that the species was Northwestern Gartersnake, we measured the habitat at the location where we encountered the snake and at a paired-random location.

We also recorded whether each capture took place on a transect search to determine the relative frequency that snakes were found on edges, or edge search to determine what characteristics of edges were important. We analysed edge and transect search effort using data from 29 May to 8 September 2012. We performed all data analyses using R (R Core Team 2012).

We tested all variables for normality using Shapiro-Wilks tests and assessed the correlation of each possible pair of variables. We ran analyses on all captures grouped as a whole and on subsets of snakes divided by survey type, sex, size class, and digestive state. We omitted recaptures due to small sample size ($n = 3$) and we also excluded all individuals found under cover objects because we found relatively few of them ($n = 7$) and therefore focused our study on active snakes. We chose to combine all observations across all five field sites because no one site was distinct based on principal components analysis or Kruskal-Wallis tests (Dixon-MacCallum 2013). For matched-pairs logistic regression, described below, we could not include SVL in models, and therefore needed to define size classes to be able to fit models to subsets of individuals in those classes.

Because our data were non-normal, we used a non-parametric Wilcoxon sign-rank test, instead of a parametric paired t -test, to compare the distance from each capture point to the nearest habitat edge and the distance from each random point to the nearest habitat edge. We first performed this test using all captures, regardless of survey type. We then retested after removing all individuals captured on edge surveys. We also

TABLE 1. Habitat variables measured at each Northwestern Gartersnake (*Thamnophis ordinoides*) capture location and associated random point and P -values for univariate matched-pair logistic regression models for snakes captured while surveying edges ($n = 84$). Variables for which $P < 0.25$ were included in a global matched pair logistic regression model and are highlighted with *; positive estimates are indicated with (+) and negative estimates with (-).

Variable	Description	All snakes
HerbVeg	Herbaceous vegetation < 30 cm tall (% of 1 m ²)	0.070 (-)*
WoodyVeg	Woody vegetation < 30 cm tall (% of 1 m ²)	0.100 (-)*
CoverObj	Logs, rocks, or garbage >20 cm (% of 1 m ²)	0.090 (-)*
Sticks	Sticks (% of 1 m ²)	0.450 (-)
SmRocks	Rocks < 20 cm (% of 1 m ²)	0.520 (-)
BareGround	Bare substrate or moss (% of 1 m ²)	0.010 (-)*
Stems	Number of woody stems in 1 m ²	0.880 (-)
Canopy	Canopy cover (%), measured 1 m from ground with spherical densiometer	0.090 (-)*
Slope	Slope of plot	0.700 (-)
Aspect	Aspect at plot (° from 0)	0.490 (-)
DistEdge	Distance from centre of plot to nearest habitat edge (m)	0.001 (-)
Temp	Substrate temperature (°C)	0.650 (-)
LitterDepth	Litter depth (cm)	0.040 (-)*

conducted an ANCOVA to test the effect of habitat type (i.e., forest or field) on snake captures with search time as a covariate.

Matched pair logistic regression is a form of logistic (i.e., binomial) regression modelling designed for use with paired data (Hosmer and Lemeshow 2000). This type of regression is more powerful for paired datasets than standard logistic regression because it focuses on differences between pairs of data collected together. In standard logistic regression it is assumed that each observation is independent (Manly *et al.* 2002). However, in a paired study, a random point is measured only if there is a capture to which it can be paired. As such, the number of random points is dependent upon the number of individuals captured. Therefore, although each pair is independent from each other pair, captures and paired points are not independent. By taking the difference between the values measured at capture and paired points one can form a dataset of differences, each of which is independent of all others. We subtracted the values measured at random locations from those at capture locations to obtain habitat differences and regressed those differences against a response of all ones (capture minus paired, or $1 - 0$) with the intercept omitted (Hosmer and Lemeshow 2000). We selected variables for inclusion in a global model by fitting a univariate logistic regression model to obtain estimated coefficients and P values. We included any variable in the global model that had a P value < 0.25 (Row and Blouin-Demers 2006). Hosmer and Lemeshow (2000) suggest that using $P < 0.25$ ensures that all variables of potential importance are included in the initial model. We fitted these univariate models using all Northwestern Gartersnakes captured excluding those captured on transects and those found under cover objects (Table 1). We also fitted models for large snakes, small snakes, gravid females, and postprandial snakes. However, each of these models was based on relatively small samples, each fewer than 30, and global models fit poorly; we therefore excluded these models from further analysis.

Typically, model selection is performed by choosing a set of candidate models *a priori*, then fitting each model and comparing output to choose best models and models for averaging (Mazerolle 2006). Our method differs in that we developed our set of candidate models by fitting all possible combinations of variables selected by the method described above. We followed this method because we hypothesized that all the variables we measured (Table 1) could potentially play some role in habitat use for this species. Therefore, we were interested in determining which combination of those variables could best describe habitat use for this species.

We used bootstrapping to assess the overall fit of our models using the function *Boot*, in the package *car* (Fox and Weisberg 2011). Bootstrapping is a process of internal validation that can be used for re-sampling many kinds of datasets (Westfall and Young 1993). Bootstrapping involves randomly sampling the original

dataset, with replacement, to obtain new datasets that can then be used to recalculate the values of interest. Steyerberg *et al.* (2001) reviewed several methods of internal validation for logistic regression models and found that standard bootstrap methods were best for establishing reliable estimates and standard errors. We ran 999 iterations and compared estimates and standard errors to those generated from our original model. We adapted the method in Steyerberg *et al.* (2001) and considered models to have a good fit if estimates and standard errors from bootstrapping overlapped the estimates and standard errors from model fitting. We fitted a global model, with all variables of potential interest and tested the fit of this model by bootstrapping and comparing bootstrap estimates to model coefficients and standard errors. Bootstrap estimates of model coefficients and their standard errors suggested a good model fit. Estimates and standard errors overlapped for all variables and bias was low.

Where the global model has an adequate fit, models fitted with the same dataset and a subset of those parameters will have a good fit as well (Mazerolle 2006). We used the function *glmulti* from the R package *glmulti* (Calcagno 2013) to select candidate models. *Glmulti* is a package that performs automated model selection by fitting a model for every combination of variables in the global model and ranking the models by AIC_c values. Models within $2 AIC_c$ (i.e., ΔAIC_c 0–2) of the best model have substantial support, those with a ΔAIC_c of 4–7 have considerably less support, and those with a $\Delta AIC_c > 10$ have essentially no support (Burnham and Anderson 2002: 70). We considered all models with $\Delta AIC_c < 7$ and selected models with $\Delta AIC_c < 2$ for model averaging. We conducted model averaging to determine parameter estimates and standard errors following Burnham and Anderson (2002). We fitted matched-pair logistic regression models for all Northwestern Gartersnakes captured on habitat edges.

Results

We collected habitat data at 130 capture points and 130 paired points. For nine of these 130 pairs we collected habitat data despite being unable to capture the snake. We captured 84 snakes on edge searches, 25 on transects, 16 snakes while walking into study sites or while relocating, and captured five snakes haphazardly (e.g., while walking to a paired plot). We recaptured only three snakes and these recaptures were omitted from further analysis.

Capture sites were closer to the nearest habitat edge than were random sites ($n = 130$, $W = 760.5$, $P < 0.0001$; Figure 1A). This relationship was maintained even after we removed all captures made during edge focused survey ($n = 46$, $W = 165.5$, $P = 0.003$; Figure 1B). Of the 84 snakes captured while surveying habitat edges, 60 were captured in 2536 min searching in open habitats, such as field edges where short grass borders with tall grass or shrubs, and 24 were captured in 2147 min

searching forest edges, where fields or shrubs border with trees. Therefore, in fields we searched approximately 42 min for every snake captured and in forests we searched 89 min for each snake captured. However, there is no significant effect of habitat type on snake capture, after controlling for search time ($F_{1,8} = 0.79$, $P = 0.40$).

For all Northwestern Gartersnakes sampled, six variables were significant at the $P < 0.25$ level (Table 1). We fitted 20 models overall, 12 models had a $\Delta AIC_c < 7$ (Table 2), three of which had $\Delta AIC_c < 2$ (Table 2). Habitat edges where we found Northwestern Gartersnakes have lower proportions of bare ground and woody vegetation than was available at random points (Table 3). Northwestern Gartersnakes are also associated with locations with high proportions of potential cover objects and herbaceous vegetation (Table 3). However, the confidence limit for herbaceous vegetation overlaps zero indicating the relationship is non-significant (Table 3). Northwestern Gartersnakes also used habitat edges with some canopy cover (Table 3), despite that we typically found them in fields rather than forests.

Discussion

Our results suggest that Northwestern Gartersnakes are associated with habitat edges. One potential criticism of this conclusion is that it is biased by the differential visibility of snakes in different habitats. That is,

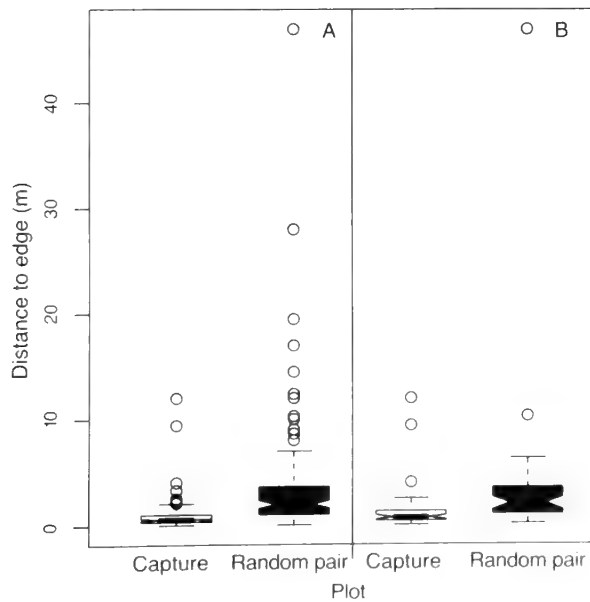


FIGURE 1. Boxplots of Distance to edge (m) at Northwestern Gartersnake (*Thamnophis ordinoides*) capture plots (white) and random-paired plots (grey). A) All captures and paired-random plots, $n = 130$, $W = 760.5$, $P < 0.0001$. B) Captures and paired-random plots with edge searches removed, $n = 46$, $W = 165.5$, $P = 0.003$. Whiskers extend to 1.5 times the interquartile range; beyond the whiskers extreme values are indicated as hollow circles.

TABLE 2. Log-likelihood and associated values for models within 7 AIC_c of the best matched pair logistic regression model for Northwestern Gartersnakes (*Thamnophis ordinoides*) captured while surveying edges. Model 6 is the global model; 20 models were tested overall.

Model	Model ID	Log-likelihood	k	AIC _c	ΔAIC _c	Akaike weight
Canopy + Litter + Cover + BareGround	1	-41.49	4	91.48	0.00	0.34
Canopy + Litter + CoverObj. + WoodyVeg. + BareGround	2	-41.24	5	93.25	1.77	0.14
HerbVeg + Canopy + Litter + CoverObj. + BareGround	3	-41.35	5	93.47	1.99	0.13
Canopy + Litter + BareGround	4	-43.81	3	93.91	2.43	0.10
Litter + CoverObj. + BareGround	5	-44.10	3	94.51	3.03	0.08
HerbVeg + Canopy + Litter + CoverObj. + WoodyVeg + BareGround	6	-41.14	6	95.37	3.89	0.05
HerbVeg + Canopy + Litter + BareGround	7	-43.63	4	95.76	4.28	0.04
Canopy + Litter + WoodyVeg + BareGround	8	-43.76	4	96.02	4.54	0.04
HerbVeg + Litter + CoverObj. + BareGround	9	-44.08	4	96.66	5.18	0.03
Litter + WoodyVeg + CoverObj. + BareGround	10	-44.10	4	96.72	5.23	0.03
Litter + BareGround	11	-46.57	2	97.29	5.81	0.02
HerbVeg + Canopy + Litter + BareGround + WoodyVeg	12	-43.60	5	97.97	6.48	0.01

TABLE 3. Variables included in averaged matched pair logistic regression model from the top three candidate models ($\Delta AIC_c < 2$) for Northwestern Gartersnakes (*Thamnophis ordinoides*) captured while surveying edges. Table includes estimates, standard error, and 95% confidence intervals (CI).

	Variable	Estimate	Std. error	95% CI
Litter	-0.237	0.045	-0.324	-0.148
CoverObj	0.283	0.112	0.062	0.500
BareGround	-0.044	0.011	-0.065	-0.022
Canopy	0.013	0.004	0.006	0.020
WoodyVeg	-0.017	0.003	-0.024	-0.011
HerbVeg	0.003	0.003	-0.002	0.008

rather than snakes favouring edges, edges favour visibility of snakes. That said, radio-telemetry studies of other species have shown that edges are preferred habitats for some species of snakes (Row and Blouin-Demers 2006; Wisler *et al.* 2008; Reading and Jofré 2009), consistent with our findings. Thus, this conclusion is a viable hypothesis for more comprehensive future tests of habitat use in Northwestern Gartersnakes.

Snakes may use edges for multiple reasons (Row and Blouin-Demers 2006; Reading and Jofré 2009), including the possibility that edges provide thermal gradients in close proximity to vegetative cover that can be a source of prey and/or provide an escape refuge from predators. Common Gartersnakes (*Thamnophis sirtalis*) used basking sites beside paths, where they were partially hidden in vegetation but remained exposed to sunlight, and this could reflect a trade off between the need to bask and predator avoidance (Burgner *et al.* 2004).

When forests are fragmented, edges are created that are generally warmer than the interior forest (Murcia 1995). It is likely that edges of fields, where we typically found Northwestern Gartersnakes, would maintain thermal gradients in much the same way as would a forest edge. Northwestern Gartersnakes frequently consume slugs (Gregory 1984) and slugs in the genus *Arion* are more abundant at field edges than in fields (Eggenschwiler *et al.* 2013). Eastern Massasauga Rattlesnakes (*Sistrurus catenatus*) in Ontario (Harvey and Weatherhead 2006) and Western Gartersnakes (*Thamnophis elegans*) in New Mexico (Szaro *et al.* 1985) also were regularly found near vegetative cover. We frequently saw potential predators at our study sites and it is thus not surprising that Northwestern Gartersnakes would be found near vegetative cover, either because those that spend too long in the open are eaten, or because these snakes actually select locations near cover.

Aside from edges, cover objects, such as rocks, logs, and even trash are also used by many species of snakes. For example, Broad-headed Snakes (*Hoplocephalus bungaroides*) in Australia are often found under rocks, and the illegal removal of rocks has been associated with a reduction in the abundance of that species throughout its range (Webb and Shine 1998). Cover from rocks also plays an important role in thermoregulation for

Western Gartersnakes (Huey *et al.* 1989). Northern Watersnakes (*Nerodia sipedon*) in Ontario were regularly found under rocks along a river (Gregory 2009). Large and small watersnakes were found using rocks as cover, except for gravid females that were generally found in the open (Gregory 2009). Furthermore, the addition of cover objects to survey plots increased the number of snakes detected, including Common Gartersnakes, in field and forest habitats (Halliday and Blouin-Demers 2015). In our study, large rocks, logs, and other cover objects were not common at capture or random points, yet when they were present they were generally associated with Northwestern Gartersnakes. Cover objects remained important even when snakes captured underneath them were excluded from analyses. This underscores the importance of cover objects to Northwestern Gartersnakes and supports our survey method because we were able to determine that cover objects are important to this species even while omitting those individuals found under cover and out of view.

The apparent use of sites with low litter depth and low proportions of bare ground and canopy cover is more difficult to interpret. In the southeastern United States, six species of small snakes had the highest relative abundance in areas of intermediate canopy cover and intermediate litter depth relative to areas of high canopy cover with deep litter, or clearcuts with no canopy cover and very little litter (Todd and Andrews 2008). One of these species, the Northern Redbelly Snake (*Storeria occipitomaculata*), is found in similar habitats to those used by the Northwestern Gartersnake and also eats slugs and earthworms (Gilhen 1984; Semlitsch and Moran 1984), although, unlike Northwestern Gartersnakes, Northern Redbelly Snakes are active both day and night, rather than just diurnally (P.T.G., unpublished data). Also, grasssnakes in agricultural areas in Switzerland were found at sites with lower proportions of organic litter (Wisler *et al.* 2008). Perhaps shallow litter and canopy cover provide a balance between thermal quality and cover because snakes can bask near the surface while remaining partially obscured within the litter and some shade to avoid extremely high temperatures. Alternatively, because this study relied on visual encounter surveys to find snakes it is also possible that the apparent use of sites with low litter depth is due to the difficulty in detecting snakes in areas of deep litter, rather than an actual increase in abundance where litter is shallow. Further research is required to test these hypotheses.

We also found Northwestern Gartersnakes at locations with higher proportions of woody vegetation than random locations. Slugs make up a large portion of the prey of Northwestern Gartersnakes (Gregory 1984) and it is possible that sites with more woody vegetation have higher moisture content and are better habitat for slugs. Huey *et al.* (1989) observed that Western Gartersnakes that had fed recently were more likely to remain

in retreat sites (e.g., under rocks). Perhaps dense woody vegetation serves as cover while Northwestern Gartersnakes digest their food.

Unlike many other studies of habitat use by snakes (Harvey and Weatherhead 2006; Pattishall and Cundall 2009; Row *et al.* 2012), our study relied on visual encounter surveys, rather than radio-telemetry, and was therefore limited to a description of the habitat occupied by snakes that we could detect. One advantage of this approach is that we base our conclusions on habitat characteristics of locations of many individuals, rather than the small samples of individuals typical of radio-telemetry studies (Harvey and Weatherhead 2006; Wisler *et al.* 2008; Shew *et al.* 2012). However, the strength of radio-telemetry is that it allows those few individuals to be re-located many times, even in places where they cannot be seen, thereby providing much more detail on actual habitat use than the 'snapshots' that we took. Unfortunately, except for the largest adult females, the small size of the snakes we studied precluded use of radio-telemetry and the approach that we took may be the only one feasible for small snakes that are generally understudied compared to larger species (Blouin-Demers *et al.* 2007). It is almost certain that Northwestern Gartersnakes use some habitat features in which we could never detect them, such as slash piles, or thorny thickets. Radio-telemetry of adult females would allow estimates of use of such habitat types. Even among large species of snakes, however, the ecology of small immature snakes is poorly understood and they may well use habitats differently from adults (e.g., cover; Webb and Whiting 2005). Coating snakes in fluorescent powder and tracking the trails left after they are released has been used to track individuals hundreds of metres (Furman *et al.* 2011), and could be used, over short time periods, to track snakes that are too small for radio-telemetry. Also, we acknowledge that separating our capture and paired points by a random distance between 1 m and 50 m would have been superior to separating them by 50 m every time. However, due to the extreme heterogeneity of the habitat at our field sites the likelihood of a random point being near an edge was very high.

The need to thermoregulate drives habitat use patterns for these animals, and field edges presumably provide temperature gradients that are vital for many aspects of their lives. In urban parks, the maintenance of trail systems and grassy fields for recreation provides edges that snakes will use, provided that vegetated areas are available in which snakes can forage and escape predators. Also, that these snakes use organic litter as well suggests that perhaps leaving cuttings from landscaping may benefit snakes. Some species of snakes also use piles of branches for thermoregulation and leaving similar piles within urban parks could be beneficial to snakes in Saanich. Rocks and logs are often removed from areas within parks that are designated for recreation, sports fields or trails, reducing cover avail-

ability for snakes. When cover objects are removed from recreational areas, rather than removing them from the park altogether, moving them to unmanicured areas within that park may help counteract their absence elsewhere. Park managers that wish to balance snake habitat and recreation opportunities should maintain parks as a matrix of natural areas, trails, and sports fields that provide thermal gradients, foraging opportunities, and cover.

Ultimately, visual encounter surveys allowed us to obtain preliminary descriptions of patterns of habitat use on edges for Northwestern Gartersnakes. However, due to likely differences in detectability of snakes in different habitats, we do not claim that our study demonstrates preference by Northwestern Gartersnakes for edges relative to other habitats (although that remains a working hypothesis for future test), but it does suggest that these snakes commonly use such habitats and that those habitats are therefore important. Ideally, studies of habitat use for small snake species would incorporate visual encounter surveys, including inspection of cover objects, drift fences, pit-fall traps, and radio-telemetry to address differential use for all size classes.

Acknowledgements

This research was funded by a Discovery Grant from the National Science and Engineering Research Council of Canada to P.T.G. and an internal research grant from the University of Victoria. We also thank the Swan Lake and Christmas Hill Nature Sanctuary and the Municipality of Saanich for permission to undertake this work. Snakes were captured under permit from the British Columbia Ministry of Environment following procedures approved by the University of Victoria Animal Care Committee (Standard Operating Procedure # HP2002).

Literature Cited

- Bastille-Rousseau, G., D. Fortin, and C. Dussault.** 2010. Inference from habitat-selection analysis depends on foraging strategies. *Journal of Animal Ecology* 79: 1157–1163. <https://doi.org/10.1111/j.1365-2656.2010.01737.x>
- Blouin-Demers, G., L. P. G. Bjorgan, and P. J. Weatherhead.** 2007. Changes in habitat use and movement patterns with body size in Black Ratsnakes (*Elaphe obsoleta*). *Herpetologica* 63: 421–429. [https://doi.org/10.1655/0018-0831\(2007\)63\[421:CHUAM\]2.0.CO;2](https://doi.org/10.1655/0018-0831(2007)63[421:CHUAM]2.0.CO;2)
- Blouin-Demers, G., and P. J. Weatherhead.** 2001a. Habitat use by Black Rat Snakes (*Elaphe obsoleta obsoleta*) in fragmented forests. *Ecology* 82: 2882–2896. <https://doi.org/10.2307/2679968>
- Blouin-Demers, G., and P. J. Weatherhead.** 2001b. An experimental test of the link between foraging, habitat selection and thermoregulation in Black Rat Snakes *Elaphe obsoleta obsoleta*. *Journal of Animal Ecology* 70: 1006–1013. <https://doi.org/10.1046/j.0021-8790.2001.00554.x>
- Burger, J., C. Jeitner, H. Jensen, M. Fitzgerald, S. Carlucci, S. Shukla, S. Burke, R. Ramos, and M. Gochfeld.** 2004. Habitat use in basking Northern Water (*Nerodia sipedon*)

- and Eastern Garter (*Thamnophis sirtalis*) Snakes in urban New Jersey. *Urban Ecosystems* 7: 17–27. <https://doi.org/10.1023/b:ueco.0000020169.86700.76>
- Burnham, K. P., and D. R. Anderson.** 2002. *Model Selection and Multi-Model Inference: A Practical Information-Theoretic Approach*. Springer-Verlag New York Inc., New York, New York, USA. <https://doi.org/10.1007/b97636>
- Calcagno, V.** 2013. glmulti: model selection and multimodel inference made easy. R package version 1.0.7. <http://CRAN.R-project.org/package=glmulti>.
- Charland, M. B., and P. T. Gregory.** 1995. Movements and habitat use in gravid and nongravid female garter snakes (Colubridae: *Thamnophis*). *Journal of Zoology* 236: 543–561. <https://doi.org/10.1111/j.1469-7998.1995.tb02731.x>
- DeStefano, S., and R. M. DeGraaf.** 2003. Exploring the ecology of suburban wildlife. *Frontiers in Ecology and the Environment* 1: 95–101. <https://doi.org/10.2307/3868036>
- Dixon-MacCallum, G.** 2013. *Habitat use by Northwestern Gartersnakes (Thamnophis ordinoides) in Saanich, British Columbia*. M.Sc. thesis, University of Victoria, Victoria, British Columbia, Canada.
- Eggenschwiler, L., B. Speiser, A. Bosshard, and K. Jacot.** 2013. Improved field margins highly increase slug activity in Switzerland. *Agronomy for Sustainable Development* 33: 349–354. <https://doi.org/10.1007/s13593-012-0101-1>
- Elzer, A. L., D. A. Pike, J. K. Webb, K. Hammill, R. A. Bradstock, and R. Shine.** 2013. Forest-fire regimes affect thermoregulatory opportunities for terrestrial ectotherms. *Austral Ecology* 38: 190–198. <https://doi.org/10.1111/j.1442-9993.2012.02391.x>
- Fox, J., and S. Weisberg.** 2011. *An R Companion to Applied Regression*. Second edition. Sage Publications, Thousand Oaks, California, USA.
- Furman, B. L. S., B. R. Scheffers, and C. A. Paszkowski.** 2011. The use of fluorescent powdered pigments as a tracking technique for snakes. *Herpetological Conservation and Biology* 6: 473–478.
- Germaine, S. S., and B. F. Wakeling.** 2001. Lizard species distributions and habitat occupation along an urban gradient in Tucson, Arizona, USA. *Biological Conservation* 97: 229–237. [https://doi.org/10.1016/S0006-3207\(00\)00115-4](https://doi.org/10.1016/S0006-3207(00)00115-4)
- Gilhen, J.** 1984. *Amphibians and Reptiles of Nova Scotia*. Nova Scotia Museum, Halifax, Nova Scotia, Canada.
- Gregory, P. T.** 1984. Habitat, diet, and composition of assemblages of garter snakes (*Thamnophis*) at eight sites on Vancouver Island. *Canadian Journal of Zoology* 62: 2013–2022. <https://doi.org/10.1139/z84-295>
- Gregory, P. T.** 2009. Variation in size of cover used by water-snakes (*Nerodia*): do smaller snakes use smaller rocks? *Acta Oecologica* 35: 182–187. <https://doi.org/10.1016/j.actao.2008.09.008>
- Halliday, W. D., and G. Blouin-Demers.** 2015. Efficacy of coverboards for sampling small northern snakes. *Herpetology Notes* 8: 309–314.
- Harvey, D. S., and P. J. Weatherhead.** 2006. A test of the hierarchical model of habitat selection using Eastern Massasauga Rattlesnakes (*Sistrurus c. catenatus*). *Biological Conservation* 130: 206–216. <https://doi.org/10.1016/j.biocon.2005.12.015>
- Helden, A. J., and S. R. Leather.** 2004. Biodiversity on urban roundabouts – Hemiptera, management and the species-area relationship. *Basic and Applied Ecology* 5: 367–377. <https://doi.org/10.1016/j.baae.2004.06.004>
- Hosmer, D. W., and S. Lemeshow.** 2000. *Applied Logistic Regression*. Second edition. John Wiley and Sons Inc., New York, New York, USA. <https://doi.org/10.1002/0471722146>
- Huey, R. B., C. R. Peterson, S. J. Arnold, and W. P. Porter.** 1989. Hot rocks and not-so-hot rocks: retreat-site selection by garter snakes and its thermal consequences. *Ecology* 70: 931–944. <https://doi.org/10.2307/1941360>
- Hurlbert, S. H.** 1984. Pseudoreplication and the design of ecological field experiments. *Ecological Monographs* 54: 187–211. <https://doi.org/10.2307/1942661>
- Johnson, M. D.** 2007. Measuring habitat quality: a review. *The Condor* 109: 489–504. <https://doi.org/10.1650/8347.1>
- Lawson, P. M. A.** 1991. *Movement patterns and orientation mechanisms in garter snakes*. M.Sc. thesis, University of Victoria, Victoria, British Columbia, Canada.
- Lutterschmidt, W. I., and H. K. Reinert.** 1990. The effect of ingested transmitters upon the temperature preference of the Northern Water Snake, *Nerodia S. sipedon*. *Herpetologica* 46: 39–42.
- Madsen, T.** 1987. Cost of reproduction and female life-history tactics in a population of Grass Snakes, *Natrix natrix*, in southern Sweden. *Oikos* 49: 129–132. <https://doi.org/10.2307/3566017>
- Manly, B. F. J., L. L. McDonald, D. L. Thomas, T. L. McDonald, and W. P. Erickson.** 2002. *Resource Selection by Animals: Statistical Design and Analysis for Field Studies*. Kluwer Academic, Dordrecht, the Netherlands, Boston, Massachusetts, USA. <https://doi.org/10.1007/978-94-011-1558-2>
- Mazerolle, M. J.** 2006. Improving data analysis in herpetology: using Akaike's Information Criterion (AIC) to assess the strength of biological hypotheses. *Amphibia-Reptilia* 27: 169–180. <https://doi.org/10.1163/156853806777239922>
- Molloy, I. A.** 2011. Habitat distribution of the amphibians and reptiles in the city of Plovdiv, Bulgaria. *Biharean Biologist* 5: 25–31.
- Murcia, C.** 1995. Edge effects in fragmented forests: Implications for conservation. *Trends in Ecology & Evolution* 10: 58–62. [https://doi.org/10.1016/S0169-5347\(00\)88977-6](https://doi.org/10.1016/S0169-5347(00)88977-6)
- Pattishall, A., and D. Cundall.** 2009. Habitat use by Synurbic Watersnakes (*Nerodia sipedon*). *Herpetologica* 65: 183–198. <https://doi.org/10.1655/08-038r2.1>
- R Core Team.** 2012. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. <http://www.R-project.org>.
- Reading, C. J., and G. M. Jofré.** 2009. Habitat selection and range size of Grass Snakes *Natrix natrix* in an agricultural landscape in southern England. *Amphibia-Reptilia* 30: 379–388. <https://doi.org/10.1163/156853809788795164>
- Reinert, H. K.** 1993. Habitat selection in snakes. Pages 201–240 in *Snakes: Ecology and Behavior*. Edited by R. A. Seigel and J. T. Collins. McGraw-Hill Inc., Whitby, Ontario, Canada.
- Reinert, H. K., and D. Cundall.** 1982. An improved surgical implantation method for radio-tracking snakes. *Copeia* 1982: 702–705. <https://doi.org/10.2307/1444674>
- Row, J. R., and G. Blouin-Demers.** 2006. Thermal quality influences habitat selection at multiple spatial scales in milksnakes. *Ecoscience* 13: 443–450. [https://doi.org/10.2980/1195-6860\(2006\)13\[443:qihhsa\]2.0.co;2](https://doi.org/10.2980/1195-6860(2006)13[443:qihhsa]2.0.co;2)
- Row, J. R., G. Blouin-Demers, and S. C. Lougheed.** 2012. Movements and habitat use of Eastern Foxsnakes (*Pantherophis gloydi*) in two areas varying in size and fragmentation. *Journal of Herpetology* 46: 94–99. <https://doi.org/10.1670/10-262>

- Semlitsch, R. D., and G. B. Moran.** 1984. Ecology of the Redbelly Snake (*Storeria occipitomaculata*) using mesic habitats in South Carolina. *American Midland Naturalist* 111: 33–40. <https://doi.org/10.2307/2425539>
- Shew, J. J., B. D. Greene, and F. E. Durbian.** 2012. Spatial ecology and habitat use of the Western Foxsnake (*Pantherophis vulpinus*) on Squaw Creek National Wildlife Refuge (Missouri). *Journal of Herpetology* 46: 539–548. <https://doi.org/10.1670/10-111>
- Soulé, M. E.** 1991. Land use planning and wildlife maintenance: guidelines for conserving wildlife in an urban landscape. *Journal of the American Planning Association* 57: 313–323. <https://doi.org/10.1080/01944369108975502>
- Stebbins, R. C.** 2003. *A Field Guide to Western Reptiles and Amphibians*. Third edition. Houghton Mifflin, Boston, Massachusetts, USA.
- Stevenson, R. D., C. R. Peterson, and J. S. Tsuji.** 1985. The thermal dependence of locomotion, tongue flicking, digestion, and oxygen consumption in the Wandering Garter Snake. *Physiological Zoology* 58: 46–57. <https://doi.org/10.1086/physzool.58.1.30161219>
- Stewart, G. R.** 1968. Some observations on the natural history of two Oregon garter snakes (Genus *Thamnophis*). *Journal of Herpetology* 2: 71–86. <https://doi.org/10.2307/1563105>
- Steyerberg, E. W., F. E. Harrell, Jr., G. J. J. Borsboom, M. J. Eijkemans, Y. Vergouwe, and J. D. F. Habbema.** 2001. Internal validation of predictive models: efficiency of some procedures for logistic regression analysis. *Journal of Clinical Epidemiology* 54: 774–781. [https://doi.org/10.1016/S0895-4356\(01\)00341-9](https://doi.org/10.1016/S0895-4356(01)00341-9)
- Szaro, R. C., S. C. Belfit, J. K. Aitkin, and J. N. Rinne.** 1985. Impact of grazing on a riparian garter snake. Pages 359–363 in *Riparian Ecosystems and their Management: Reconciling Conflicting Uses*. USDA Forest Service General Technical Report RM-120. Edited by R. R. Johnson, C. D. Ziedell, D. R. Patton, P. F. Folliott, and F. H. Hamre. U.S. Department of Agriculture Forest Service, Fort Collins, Colorado, USA.
- Thomas, D. L., and E. J. Taylor.** 2006. Study designs and tests for comparing resource use and availability II. *The Journal of Wildlife Management* 70: 324–336. [https://doi.org/10.2193/0022-541x\(2006\)70\[324:sdatfc\]2.0.co;2](https://doi.org/10.2193/0022-541x(2006)70[324:sdatfc]2.0.co;2)
- Todd, B. D., and K. M. Andrews.** 2008. Response of a reptile guild to forest harvesting. *Conservation Biology* 22: 753–761. <https://doi.org/10.1111/j.1523-1739.2008.00916.x>
- Weatherhead, P. J., J. H. Sperry, G. L. F. Carfagno, and G. Blouin-Demers.** 2012. Latitudinal variation in thermal ecology of North American ratsnakes and its implications for the effect of climate warming on snakes. *Journal of Thermal Biology* 37: 273–281. <https://doi.org/10.1016/j.jtherbio.2011.03.008>
- Webb, J. K., and R. Shine.** 1998. Using thermal ecology to predict retreat-site selection by an endangered snake species. *Biological Conservation* 86: 233–242. [https://doi.org/10.1016/S0006-3207\(97\)00180-8](https://doi.org/10.1016/S0006-3207(97)00180-8)
- Webb, J. K., and M. J. Whiting.** 2005. Why don't small snakes bask? Juvenile Broad-Headed Snakes trade thermal benefits for safety. *Oikos* 110: 515–522. <https://doi.org/10.1111/j.0030-1299.2005.13722.x>
- Westfall, P. H., and S. S. Young.** 1993. *Resampling-Based Multiple Testing: Examples and Methods for P-Value Adjustment*. John Wiley and Sons Inc., New York, New York, USA.
- Wisler, C., U. Hofer, and R. Arlettaz.** 2008. Snakes and monocultures: habitat selection and movements of female Grass Snakes (*Natrix natrix* L.) in an agricultural landscape. *Journal of Herpetology* 42: 337–346. <https://doi.org/10.1670/07-027.1>

Received 5 January 2016

Accepted 15 March 2017

Inexpensive Video Drop-camera for Surveying Sensitive Benthic Habitats: Applications from Glass Sponge (Hexactinellida) Reefs in Howe Sound, British Columbia

LENA CLAYTON^{1,3} and GLEN DENNISON²

¹Marine Life Sanctuary Society of British Columbia, P.O. Box 54193, Lonsdale West, North Vancouver, British Columbia V7M 3L5 Canada

²Triumpf, 4004 Wesbrook Mall, Vancouver, British Columbia V6T 2A3 Canada

³Corresponding author: lenaclayton@mlssbc.com

Clayton, Lena, and Glen Dennison. 2017. Inexpensive video drop-camera for surveying sensitive benthic habitats: applications from glass sponge (Hexactinellida) reefs in Howe Sound, British Columbia. *Canadian Field-Naturalist* 131(1): 46–54. <https://doi.org/10.22621/cfn.v131i1.1783>

Where marine waters are shallow and bathymetric features are steep, the typically employed multi-beam side scan sonar is not always reliable for identifying complex biological structures. Here, we present a cost-efficient method used in Howe Sound, British Columbia, for bathymetric mapping, exploration, and ground-truthing of glass sponge bioherms. A simple depth sounder and software package was used to produce bathymetric maps. From these maps, prospective sites were selected and surveyed to investigate bioherm presence with a simple drop-camera towed off the bow of a small drifting vessel during calm seas. This method was used during a 4-year citizen science initiative that led to the discovery of 12 glass sponge bioherms in Howe Sound, the first step in protecting these globally unique reefs from the impact of bottom-contact fishing, anchoring, and potential industrial contamination. Before our work using this method, only two glass sponge bioherms had been identified in Howe Sound. The method also proved effective as a means to quantify damage to bioherms from fishing gear.

Key Words: Bioherms; citizen science; drop-camera; glass sponge; sensitive benthic habitats; Howe Sound

Introduction

Glass sponges are sessile organisms that can form geologically stable habitats, or bioherms, through the accumulation of ancestral skeletal matter and sediment (Cumings and Shrock 1928; Conway *et al.* 2001; Krautter *et al.* 2001). These unique habitats, with live sponges growing on top, first appeared during the Devonian period and were abundant throughout the Late Jurassic (Ghiold 1991). Bioherms were thought to have no current living analog until their discovery in Queen Charlotte Sound and Hecate Strait in 1987 (Conway *et al.* 1991). Bioherms are known to provide important habitat for fish and invertebrates (Marliave *et al.* 2009; Hogg *et al.* 2010), along with mass water filtration (Yahel *et al.* 2007). However, they are at risk of damage from anthropogenic activities, such as fishing, and from pollution and are particularly sensitive benthic habitats (Wassenberg *et al.* 2002; Cook *et al.* 2008). Our ability to protect these habitats from damage relies, in part, on our knowledge of their locations.

Since the first discovery of glass sponge bioherms on the western continental shelf of Canada, further exploration has taken place to locate and map bioherms in the Strait of Georgia and Howe Sound (Conway *et al.* 2001, 2005; Krautter *et al.* 2001; Chu and Leys 2010). A combination of multi-beam sonar and remotely operated vehicle (ROV) or submersible transects have been used to investigate deep water coral and sponge garden habitat (Conway *et al.* 1991, 2001, 2005; Krautter *et al.* 2001; Leys *et al.* 2004; Chu and Leys 2010; Neves *et*

al. 2014). As well, SCUBA has been employed to supplement ROV ground-truthing in multi-beam surveys of non-glass sponge bioherm benthos (Kendall *et al.* 2005; Micallef *et al.* 2012). In Howe Sound, two bioherm sites have been located using multi-beam side scan sonar equipment and ground-truthed by ROV by Fisheries and Oceans Canada (A. Dunham, personal communication, 11 March 2014). To protect this ecologically important and sensitive habitat, bottom-contact fishing, such as commercial and recreational prawn and crab trap fisheries, has been prohibited in these areas as of 12 June 2015 (Fisheries and Oceans Canada 2016).

Multi-beam sonar capitalizes on the distinctive low-intensity backscatter pattern of clay-rich sediments found in reefs compared with the higher-intensity backscatter of reflective glacial sediment that the reefs colonize (Conway *et al.* 2005). Although this method is effective for surveying large deep areas of the ocean efficiently and characterizing the abiotic benthos (Kendall *et al.* 2005), it does not allow differentiation of living and dead glass sponge reefs, nor does it have the resolution to function accurately and consistently in shallower areas with steep slopes or pinnacles (Cope land *et al.* 2013; Ybarra 2015).

To compensate for these limitations, ROVs are often used synchronously with bathymetric maps and/or sonar maps to run video transects over the seafloor for confirmation. ROVs or submersibles can provide real-time video footage of glass sponge bioherms that can confirm the true state of the reef (Leys *et al.* 2004;

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalists' Club.

Conway *et al.* 2005). However, although they are accurate for ground-truthing, ROVs and submersibles are often cost-prohibitive for even well-funded institutions and out of reach for citizen science initiatives. Furthermore, there is the risk of damage to glass sponges by direct contact with an ROV or indirect contact (as wash of the propulsion system may increase sediment load and arrest filter feeding) in such sheltered areas as fjords, where maneuverability is limited (Allwood 1986; Leys and Tompkins 2004; Tompkins-MacDonald and Leys 2008).

Although less common, SCUBA is another method of observation that can be used in the shallower glass sponge bioherms of Howe Sound. This provides a unique opportunity to observe a normally deep water habitat and the organisms themselves first-hand (Marliave *et al.* 2009). Over the years, SCUBA has proven to be a successful technique for accurately surveying other benthic habitat types and invertebrate populations at a high resolution (Everson and White 1969; Beckley and Branch 1992; Kendall *et al.* 2005; McGarvey *et al.* 2010). The primary limitations of SCUBA observation are the restricted time one can safely collect bioherm data at depth and how deep one may undertake observation. Furthermore, as noted with coral reefs, there is a risk of physical habitat damage and disease spread with increased human contact through SCUBA diving (Lamb *et al.* 2014).

Given the complex bathymetry and shallow waters in areas of Howe Sound, alternative methods for identifying and ground-truthing bioherm locations seem advisable. Drop-cameras have proven successful in supplementing single- and multi-beam echosounders, side scan sonar, and SCUBA observational data in previous

shallow water studies (Strong and Lawton 2004; Vandermeulen 2007). As well, drop-cameras have been successfully employed for fish surveys at depth, although there may be some error in findings because of the effect of light at depth on mobile organisms (Morrison and Carbines 2006; Rooper *et al.* 2015). Here we describe an inexpensive method undertaken through a citizen science initiative to discover and survey glass sponge bioherms in the fjord of Howe Sound, British Columbia.

Methods

Drop-camera Development

A small drop-camera system was custom designed to collect underwater observations of bottom substrate from small vessels at a relatively low cost (Table 1, Figure 1). The pressure housing was first modelled and stress simulated using 3D CAD and simulation software (SolidWorks version 2014 x64 edition SP5.0, Dassault Systèmes SolidWorks Corp., Waltham, Massachusetts, USA) before undergoing a series of *in-situ* pressure tests in Howe Sound and strengthening to resist a final depth of 240 m (Figure 2A).

To achieve single wire operation, the output video was bottom-side modulated to 61.25 MHz (analog channel 3) and a direct current (DC) was injected topside on the radio frequency signal before routing to the transmission line. At the bottom side, the DC power was separated off, filtered, and passed on to two switching regulators that run in constant current mode to drive two light-emitting diodes (LEDs) mounted in pods that are part of the main pressure housing (Figure 1). The LEDs were wired in a series circuit ensuring the same drive current and luminosity output. Cooling was

TABLE 1. Specifications, materials, and approximate cost of drop-camera system (excludes all labour costs for design, construction of materials, and assembly of the system).

Drop-camera components	Materials and specifications	Estimated cost, 2010 CAD
Housing	Acrylonitrile butadiene styrene tubing Clear windows were manufactured out of 1.9-cm-thick polycarbonate Depth rating of 240 m in seawater	800
Camera	Closed-circuit colour television (Panasonic) Auto-focus and auto-aperture 350 lines colour resolution	
Twin LEDs	1000 lumens	
Other camera electronics	Custom electronics and circuitry Two power supplies	
Conductor cable	300 m	500
Topside equipment	Monitor Two computers Embedded controller programmed for video data overlay VCR (RCR Electronics) Digitizer Main power supply GPS unit	2500 3800
Total estimated cost		

Note: GPS = Global Positioning System, LED = light-emitting diode, VCR = video cassette recorder, CAD = Canadian dollars.

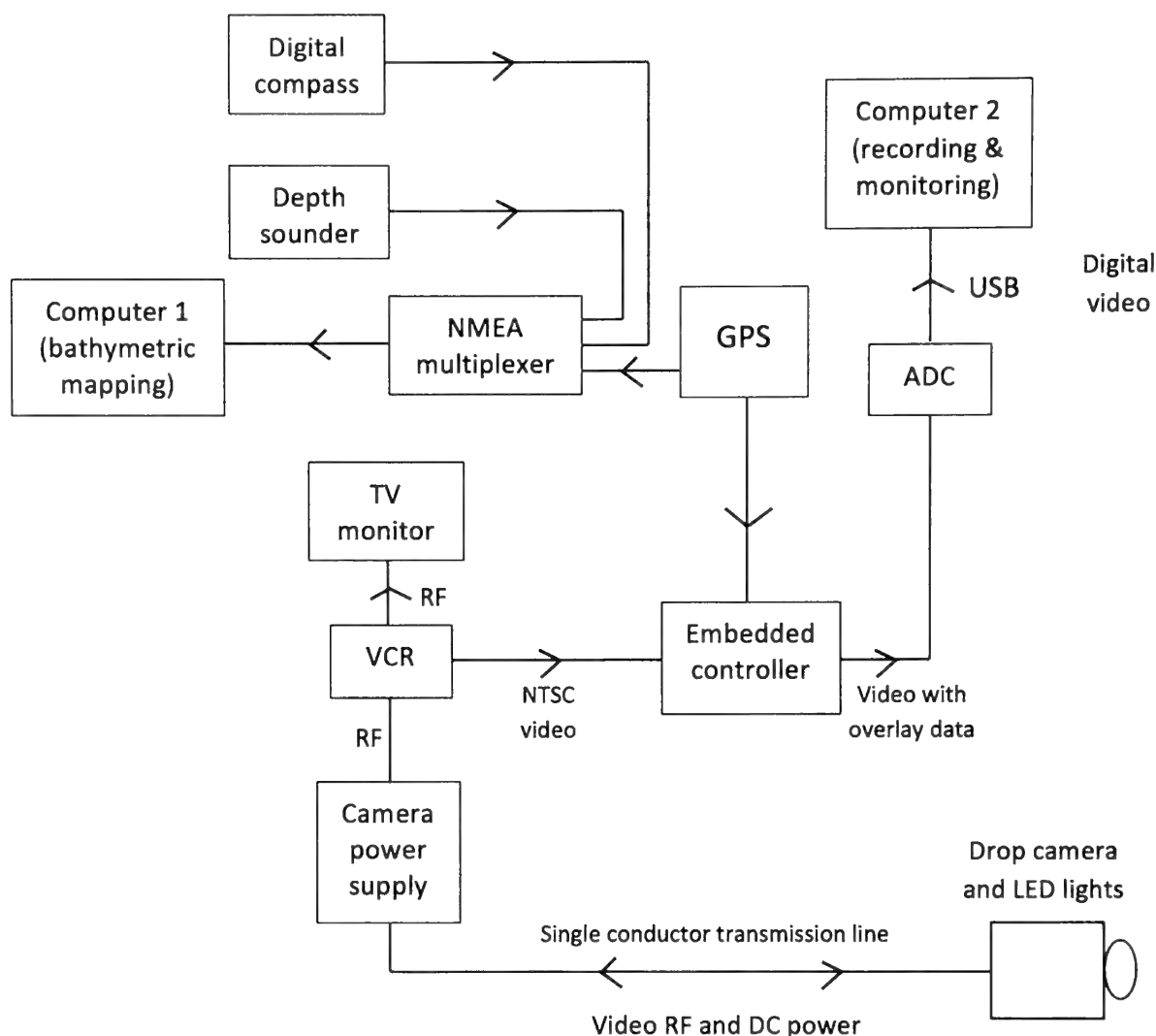


FIGURE 1. Schematic diagram of drop-camera, GPS, and bathymetric charting system. Note: ADC = analog to digital converter, DC = direct current, GPS = Global Positioning System, HD = high definition, LED = light-emitting diode, NMEA = National Marine Electronics Association, NTSC = National Television System Committee, RF = radio frequency, USB = universal serial bus, VCR = video cassette recorder.

achieved through the walls of the marine housing using two round custom-aluminium heat sinks. A closed circuit television (CCTV) camera was powered in the same way as the two LEDs. After separating from the radio frequency signal, the DC power was routed into a linear three-terminal integrated-circuit regulator to reduce and regulate the DC voltage applied to the camera.

Bathymetric Mapping

Custom bathymetric maps of potential bioherm sites were prepared using DrDepth software (version 5.0.15, created by P. Pelin in 2005, Informer Technologies, Sweden; no longer available) in conjunction with a FishFinder (model 300C, Garmin International, Inc., Olathe, Kansas, USA) with National Marine Electronics Association (NMEA) 0183 output. Positional data from the vessel's electronic compass and the FishFinder

were streamed through the NMEA highway to a custom manufactured multiplexer (NMEA 0183 Multiplexer, London, United Kingdom) along with temperature, depth, date, and time data producing a virtually continuous string of ASCII data. The multiplexer optically isolated all input channels, accepted and stored the data string, and then converted the transmission rate from 4800 baud to 115 200 baud. Before the data string was transmitted to the computer, the transmission level was changed to universal serial bus (USB). The computer received the data stream, and the DrDepth software plotted geo-positional and depth data. The software produced and recorded a series of parallel and perpendicular tracks and then used its averaging algorithms to interpolate depths between points and produce two-dimensional and three-dimensional bathymetric maps resolved to approximately 3 m on the surveyed seafloor



FIGURE 2. A. Drop-camera with LEDs and cable reel. Photo: G. Dennison. B. Drop-camera suspended over bow of boat. Photo: R. Mulder. C. 7.2-m boat employed for surveys. Photo: G. Dennison. D. Screenshot from drop-camera video footage of glass sponge bioherm. Note: although the GPS data overlay displayed minutes to four decimal places, accuracy was not that precise and the fourth number was always reported as a zero. Photo: G. Dennison and I. Clayton. E. Screenshot from supplemental high-definition video camera showing recent damage to glass sponge in Kelvin Grove Seamount bioherm. Photo: G. Dennison and I. Clayton. F. Screenshot from drop-camera showing crab prawn trap in Anvil East bioherm. Photo: G. Dennison and I. Clayton.

(Dennison 2012: 19,137). The final output was a database of bathymetric maps saved as DrD files.

Drop-camera Deployment

Exploratory video transects using the drop-camera were conducted at 20 sites throughout Howe Sound from 2011 to 2015 to investigate potential bioherm sites. The transects were conducted on mapped ridges and seamounts with depths of 20–100 m, in locations with

bathymetric features similar to those at confirmed bioherms in the Strait of Georgia (Krautter *et al.* 2001; Leys *et al.* 2004; Conway *et al.* 2005; Cook *et al.* 2008; Chu and Leys 2010). The drop-camera was lowered over the bow of a 7.6-m boat with a cable on the bow rollers (Figures 2B and C). The umbilical cable was a 305-m spool with radio frequency signal and DC power slip ring to operate the camera while it was being lifted

and lowered, which allowed the cable to serve as both the mechanical tether and the feed-line for the signal and power. Camera depth was controlled by hand-lifting and lowering the umbilical cable.

After lowering the drop-camera into the water, the vessel engine was turned off and the camera and vessel were allowed to drift over the study area. A real-time display on topside monitors allowed for depth adjustment as the camera was towed above the substrate to avoid contacting the bottom. The vessel’s surface position, derived from a chart plotter (CP160, Standard Horizon, Cypress, California, USA) with a wide-area augmentation system GPS antenna, as well as the time, date, vessel speed, and vessel heading were overlaid on the recorded drop-camera video transects. As the vessel was idle and the drift direction entirely governed by winds and prevailing currents, the drop-camera was not actively towed. Mapping surveys were conducted only when favourable satellite geometry provided a horizontal dilution of precision reading ≤ 1 . Surveys were conducted at times of low wind and current to mitigate some of the positional errors that will occur with drop-cameras released at such depths. For the purpose of this study, the camera location was assumed to be within the GPS horizontal positioning error of the vessel.

SCUBA Survey

SCUBA surveys were initially conducted at five shallower sites to investigate the presence of glass sponge bioherms. Subsequent to initial dive discovery, drop-camera transects were conducted to survey and collect geo-positional data on confirmed bioherm sites (Table 2).

Video Observations

Multiple transects were conducted in the same area to investigate features of interest, confirm bioherm presence, and delineate the area of sponge coverage. Video data were reviewed to identify glass sponge species (*Aphrocallistes vastus* or *Heterochone calyx*), substratum, and the presence or absence of bioherms. A substratum that appeared soft, silty, and complex (evidence of ancestral glass sponge detritus) was considered indicative of bioherm presence as was live glass sponge coverage greater than 50% in video frames. When both of these conditions were met, the GPS coordinates were designated as a site for a bioherm (Figure 2D).

A centre was assigned to each survey site. Central points for non-pinnacle bioherm sites were calculated by averaging the Cartesian coordinates surveyed that were considered positive for bioherm habitat. Central points for bioherms located on pinnacles were derived

TABLE 2. Locations in Howe Sound, British Columbia, where presence or absence of glass sponge bioherms was confirmed.

Study site*	Detection method	Bioherm name	Date of discovery	Location (centre)		Depth at centre, m
				Latitude, N	Longitude, W	
PRESENCE OF GLASS SPONGE BIOHERM CONFIRMED						
1	Previously discovered	Defence Island Inshore	N/A	49°34.660'	123°16.410'	N/A
2	SCUBA diving	Defence Island Pinnacle	14 November 2010	49°34.690'	123°16.266'	31
3	Drop-camera	Anvil Island East	4 October 2014	49°32.640'	123°17.220'	88
4	Drop-camera	Christie Islet A	22 October 2011	49°29.663'	123°17.831'	38
	Drop-camera	Christie Islet B	22 October 2011	49°29.676'	123°17.919'	43
	Drop-camera	Christie Islet C	22 October 2011	49°29.728'	123°17.965'	42
	Drop-camera	Christie Islet D	22 October 2011	49°29.730'	123°17.879'	44
	Drop-camera	Christie Islet E	22 October 2011	49°29.808'	123°17.949'	45
5	SCUBA diving	Lost Reef	31 January 2010	49°29.760'	123°17.880'	51
6	Drop-camera	Brunswick Point	9 March 2013	49°28.408'	123°15.003'	87
7	Drop-camera	Lions Bay Seamount	8 June 2011	49°27.277'	123°15.477'	72
8	Drop-camera	Kelvin Grove Seamount	14 April 2012	49°27.120'	123°14.820'	77
9	SCUBA diving	Halkett Point North	30 June 1996	49°26.760'	123°18.720'	32
10	Drop-camera	South Bowyer A	22 February 2014	49°24.631'	123°16.111'	79
11	Drop-camera	South Bowyer B	22 March 2014	49°24.547'	123°16.125'	82
12	Drop-camera	Cates Bay	14 February 2015	49°24.779'	123°18.199'	96
13	SCUBA diving	Dorman Point	6 October 2012	49°22.440'	123°19.260'	46
14	SCUBA diving	Passage Island South-West Complex	27 May 1984	49°20.259'	123°18.888'	24
		Passage Island SE Complex (also referred to as Howe Reef)	N/A	49°20.220'	123°17.700'	N/A
		ABSENCE OF GLASS SPONGE BIOHERM CONFIRMED				
A	Drop-camera	Porteau Sill	10 May 2014	49°33.600'	123°16.500'	89
B	SCUBA diving	Halkett Point South East	July 1996	49°26.720'	123°18.570'	40
C	Drop-camera	Halkett Point South	9 May 2015	49°25.980'	123°19.020'	152
D	Drop-camera	Hutt Island West	23 May 2015	49°24.240'	123°24.240'	96

*Sites are shown on Figure 3.
Note: N/A = not available.

from the GPS coordinate of the summit. For sites with no bioherms, we used the average of all coordinates surveyed to calculate the central point. The central geospatial coordinate was calculated using the averaged Cartesian coordinates (X, Y, Z) in a Pythagoras-based formula as follows:

Latitude (radian) = $\arctan2((X^2 + Y^2)^{1/2}, Z)$

Longitude (radian) = $\arctan2(X, Y)$

Results

Between 2011 and 2015, 12 glass sponge bioherm locations were discovered at depths of 38–96 m in Howe Sound using drop-camera surveys (Table 2).

We identified glass sponge bioherms throughout the northern and southern ranges of Howe Sound, but bioherms were limited to the eastern side of the fjord (Figure 3). Five of the identified bioherms have minimum depths between 24 m and 51 m. These were the sites first discovered and surveyed by SCUBA diving; the other 12 sites are deeper (centre depths 38–96 m) and were discovered using the drop-camera system.

Four sites (Porteau Sill, Halkett Point South East, Halkett Point South, and Hutt Island West) with favourable bathymetric features for glass sponge bioherms yielded only small or patchy glass sponge gardens or were completely devoid of a glass sponge commu-

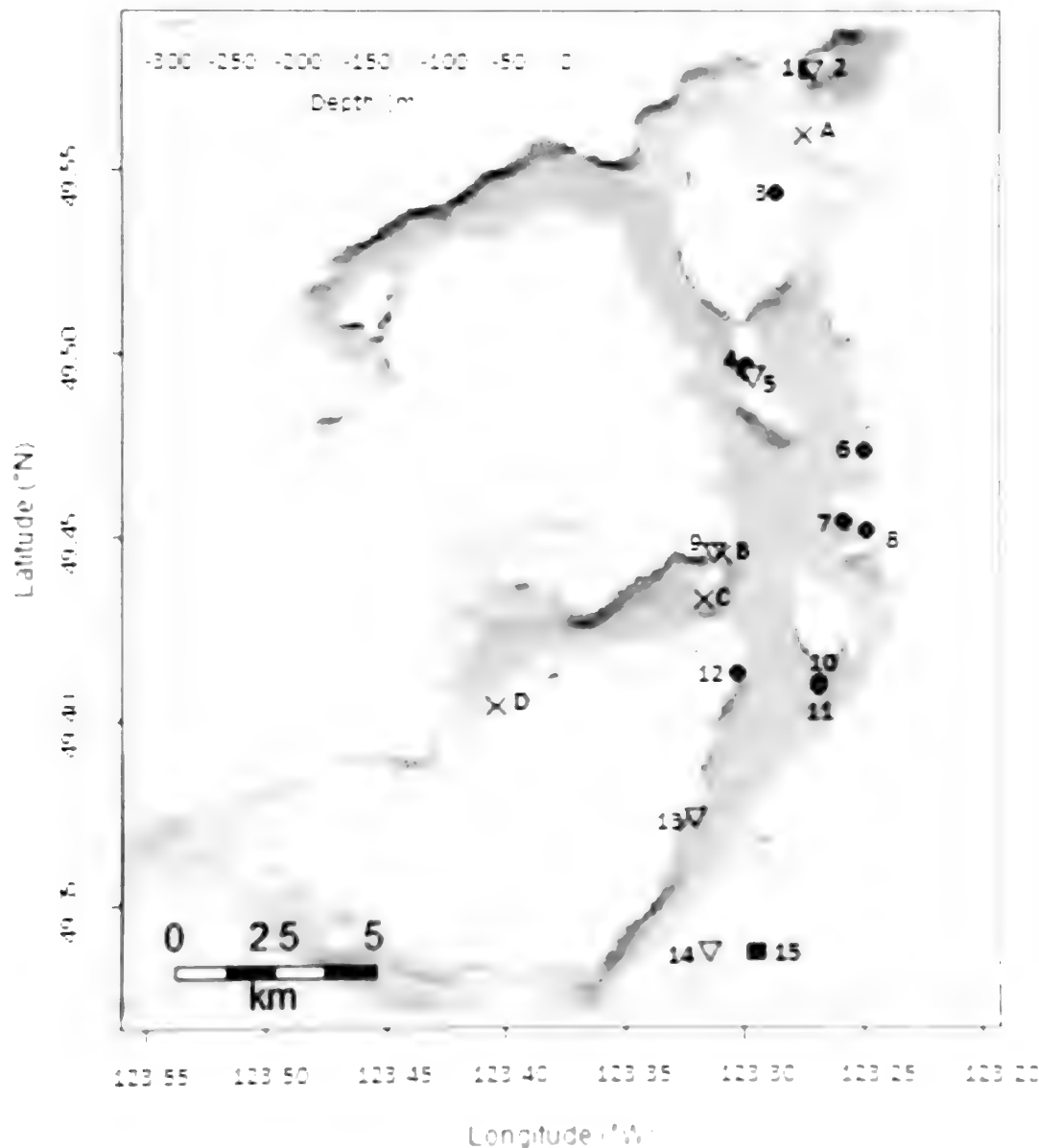


FIGURE 3. Bathymetric map of Howe Sound, British Columbia, with locations of confirmed presence or absence of glass sponge bioherms discovered through drop-camera method (● and ○, respectively) and SCUBA supplemented with drop-camera method (■). Previously known glass sponge bioherms (■) are also marked. Numbers and letters identify study sites listed in Table 2.

nity (Table 2). Qualitatively, the largest reefs known to date in Howe Sound are those we discovered in the middle of the fjord near Anvil Island and Christie Islet. Both of these are located on underwater ridges rather than pinnacles or seamounts, such as Lost Reef or the Lions Bay Seamount bioherms. Reefs in the middle of the fjord (i.e., Brunswick Point, Kelvin Grove Seamount, and Dorman Point), with the exception of the complex of shallower reefs at Christie Islet, are deeper than those at the far north (i.e., Defence Island Pinnacle) or the far south (i.e., Passage Island South-West Complex).

Three study sites included two or more distinct bioherms within their boundaries. Five distinct bioherms (A to E) were identified in close proximity to each other at Christie Islet. Two separate reefs in close proximity were also identified at Defence Island. South of Bowyer Island, two distinct bioherms were discovered.

Large areas of broken sponges were observed within the bioherms located at Halkett Point North, Kelvin Grove Seamount (Figure 2E), and Anvil Island East. Abandoned prawn traps were observed in the sponge reefs at Anvil Island (Figure 2F) and Kelvin Grove Seamount.

Discussion

With five bioherms initially discovered by SCUBA between 1984 and 2012, the existing Passage Island SE Complex bioherm (referred to as Howe Reef in some literature) surveyed by Pisces IV in the 1980s (Marliave *et al.* 2009), and the Inshore Defence Island bioherm discovered by G.D., there are now 19 sites with confirmed glass sponge bioherms in Howe Sound.

The drop-camera proved to be an effective method for locating, as well as ground-truthing, bioherms in sheltered waters such as fjords, coastal regions, estuaries, and inlets where larger equipment may be too cumbersome or function at too coarse a resolution. The drop-camera method is a passive observation tool that allows for great operator control; in the hands of a skilled operator, this method can reduce the risk of contact with glass sponges. However, the use of drifting tows can pose a challenge, because transects follow the direction in which the boat is drifting and are influenced by the prevailing currents and winds, rather than a preferred grid sampling pattern. As well, some positional errors occur when operating at depth in strong currents, as the drop-camera will not lie directly under the vessel, but at an angle.

Most underwater pinnacles and ridges surveyed at depths of 25–100 m provided positive results for bioherms. These sites were located throughout the middle of the eastern channel of Howe Sound. The most expansive bioherms observed were located in the middle of the sound and were situated on ridges, rather than on pinnacles. The apparently smaller area of other bioherms was likely a result of the physical limitation of space on small pinnacles. Although bathymetric fea-

tures proved to be a successful indicator for bioherms at several locations, four sites with promising bathymetry — Halkett Point South East, Halkett Point South, Porteau Sill, and Hutt Island West (Table 2, Figure 3) — did not support glass sponge bioherms.

Although we did not find a bioherm at Halkett Point South, bathymetric features in deep portions of this site (152 m) resemble those associated with the Halkett Point North bioherm, located 1.49 km to the north (Figure 3). The Halkett Point South East site, where we also did not find a bioherm, is 200 m east of the Halkett Point North bioherm and only 8 m deeper. The absence of glass sponge there might be because of the unsuitability of the site's specific habitat features at greater depth or proximity to the inner channel (i.e., deep currents, sedimentation, sediment load, and silica concentrations). The Porteau Sill site also lacked a glass sponge bioherm, possibly due to insufficient currents. There were no pronounced ridges or pinnacles to direct currents or increase their velocity along this portion of the sill, as is the case at the nearby Defence Island Pinnacle bioherm located on a pinnacle at 31 m depth and the inshore Defence bioherm on a small ridge. The Hutt Island West site contained clusters of individual glass sponges; however, live sponge coverage was less than 50% and the substratum was not indicative of a bioherm. We hypothesize that the apparent absence of bioherms here may be a result of contrasts in major current transport of silica divided along the eastern and western sides of the fjord. However, further surveys are required along the western side of the fjord to confirm lack of bioherms in this area.

This drop-camera method has proven successful as a tool for confirming the presence and plotting locations of glass sponge bioherms.

Although it may not be practical for all research groups to undertake the design and construction of a drop-camera system, a variety of drop-cameras capable of operating at 200 m or more are available off-the-shelf at a relatively low cost. Relative to multi-beam sonar, ROVs, and submersibles, our method is both successful and cost-effective at exploring the benthos for glass sponge bioherms. The method is, therefore, accessible to citizen scientists and smaller institutions and organizations.

Beyond surveying the benthos for glass sponge bioherms, this method also provided an unexpected secondary use: as a tool to quantify damage to bioherms from fishing gear. There was evidence of recent damage in all of the bioherms we discovered and surveyed. At some of the sites, there was clear evidence that the damage was caused by contact with fishing lines, anchors, or traps (Figures 2E and F).

These findings identify new bioherm locations in Howe Sound and provide information that can be used to protect these globally unique habitats, in existence since the Devonian (Rigby *et al.* 2001).

Acknowledgements

We sincerely thank Beau Doherty and Jeff Marliave for their invaluable assistance in developing and editing this paper. We appreciate the help of Alejandro Frid in reviewing and editing. We thank Anya Dunham, research scientist at Fisheries and Oceans Canada for sharing her knowledge. We are incredibly grateful to Marine Life Sanctuaries Society, the Vancouver Aquarium, and their all of their team members for their guidance and support.

Literature Cited

- Allwood, R. L. 1986. Environmental monitoring through the use of ROVs. Pages 355–360 in *Advances in Underwater Technology, Ocean Science and Offshore Engineering*. Volume 5. Springer Netherlands, Dordrecht, Netherlands. https://doi.org/10.1007/978-94-009-4203-5_41
- Beckley, L. E., and G. M. Branch. 1992. A quantitative scuba-diving survey of the sublittoral macrobenthos at sub-antarctic Marion Island. *Polar Biology* 11: 553–563. <https://doi.org/10.1007/BF00237948>
- Chu, J. W. F., and S. P. Leys. 2010. High resolution mapping of community structure in three glass sponge reefs (Porifera, Hexactinellida). *Marine Ecology Progress Series* 417: 97–113. <https://doi.org/10.3354/meps08794>
- Conway, K. W., J. V. Barrie, W. C. Austin, and J. L. Lutenauer. 1991. Holocene sponge bioherms on the western Canadian continental shelf. *Continental Shelf Research* 11: 771–790. [https://doi.org/10.1016/0278-4343\(91\)90079-L](https://doi.org/10.1016/0278-4343(91)90079-L)
- Conway, K. W., J. V. Barrie, and M. Krautter. 2005. Geomorphology of unique reefs on the western Canadian shelf: sponge reefs mapped by multibeam bathymetry. *Geo-Marine Letters* 25: 205–213. <https://doi.org/10.1007/s00367-004-0204-z>
- Conway, K. W., M. Krautter, J. V. Barrie, and M. Neuweiler. 2001. Hexactinellid sponge reefs on the Canadian continental shelf: a unique “living fossil.” *Geoscience Canada* 28: 71–78.
- Cook, S. E., K. W. Conway, and B. Burd. 2008. Status of the glass sponge reefs in the Georgia Basin. *Marine Environmental Research* 66: S80–S86. <https://doi.org/10.1016/j.marenvres.2008.09.002>
- Copeland, A., E. Edinger, R. Devillers, T. Bell, P. LeBlanc, and J. Wroblewski. 2013. Marine habitat mapping in support of Marine Protected Area management in a subarctic fjord: Gilbert Bay, Labrador, Canada. *Journal of Coastal Conservation* 17: 225–237. <https://doi.org/10.1007/s11852-011-0172-1>
- Cumings, E. R., and R. R. Shrock. 1928. Niagaran coral reefs of Indiana and adjacent states and their stratigraphic relations. *Bulletin of the Geological Society of America* 39: 579–620. <https://doi.org/10.1130/GSAB-39-579>
- Dennison, G. 2012. *Diving Howe Sound Reefs & Islands*. Colorcraft Ltd., Hong Kong, China.
- Everson, I., and M. G. White. 1969. Antarctic marine biological research methods involving diving. *Underwater Association of Malta Report* 4: 91–95.
- Fisheries and Oceans Canada. 2016. Strait of Georgia and Howe Sound glass sponge reef fishing closures. Fisheries and Oceans Canada, Ottawa, Ontario, Canada. Accessed 30 September 2016. http://www.pac.dfo-mpo.gc.ca/oceans/protection/sponge_reef-recif_eponge-eng.html
- Ghiold, J. 1991. The sponges that spanned Europe. *New Scientist* 129: 58–62.
- Hogg, M. M., O. S. Tendal, K. W. Conway, S. A. Pomponi, R. W. M. Soest, J. Gutt, M. Krautter, and J. M. Roberts. 2010. Deep-sea sponge grounds: reservoirs of biodiversity. Biodiversity series 32. United Nations Environment Programme World Conservation Monitoring Centre, Cambridge, United Kingdom.
- Kendall, M. S., O. P. Jensen, C. Alexander, D. Field, G. McFall, R. Bohne, and M. E. Monaco. 2005. Benthic mapping using sonar, video transects, and an innovative approach to accuracy assessment: a characterization of bottom features in the Georgia Bight. *Journal of Coastal Research* 21: 1154–1165. <https://doi.org/10.2112/03-0101R.1>
- Krautter, M., K. W. Conway, J. V. Barrie, and M. Neuweiler. 2001. Discovery of a “living dinosaur”: globally unique modern hexactinellid sponge reefs off British Columbia, Canada. *Facies* 44: 265–282. <https://doi.org/10.1007/BF02668178>
- Lamb, J. B., J. D. Truac, S. Piromvaragorn, and B. L. Willis. 2014. Scuba diving damage and intensity of tourist activities increases coral disease prevalence. *Biological Conservation* 178: 88–96. <https://doi.org/10.1016/j.biocon.2014.06.027>
- Leys, S. P., and G. J. Tompkins. 2004. Glass sponges arrest pumping in response to increased sediment loads. *Integrative and Comparative Biology* 44: 719. <https://doi.org/10.1007/s00227-008-0987-y>
- Leys, S. P., K. Wilson, C. Hopleton, H. M. Reiswig, W. C. Austin, and V. Tunnicliffe. 2004. Patterns of glass sponge (Porifera, Hexactinellida) distribution in coastal waters of British Columbia, Canada. *Marine Ecology Progress Series* 283: 133–149. <https://doi.org/10.7939/R3H41JQ09>
- Marliave, J. B., K. W. Conway, D. M. Gibbs, A. Lamb, and C. Gibbs. 2009. Biodiversity and rockfish recruitment in sponge gardens and bioherms of southern British Columbia, Canada. *Marine Biology* 156: 2247–2254. <https://doi.org/10.1007/s00227-009-1252-8>
- McGarvey, R., J. E. Feenstra, S. Mayfield, and E. V. Sautter. 2010. A diver survey method to quantify the clustering of sedentary invertebrates by the scale of spatial autocorrelation. *Marine and Freshwater Research* 61: 153–162. <https://doi.org/10.1071/MF08289>
- Micallef, A., T. P. Le Bas, V. A. Huvenne, P. Blondel, V. Hühnerbach, and A. Deidun. 2012. A multi-method approach for benthic habitat mapping of shallow coastal areas with high-resolution multibeam data. *Continental Shelf Research* 39: 14–26. <https://doi.org/10.1016/j.csr.2012.03.008>
- Morrison, M., and G. Carabines. 2006. Estimating the abundance and size structure of an estuarine population of the spard *Pagrus auratus*, using a towed camera during nocturnal periods of inactivity, and comparisons with conventional sampling techniques. *Fisheries Research* 82: 150–161. <https://doi.org/10.1016/j.fishres.2006.06.024>
- Neves, B. M., C. Du Preez, and E. Edinger. 2014. Mapping coral and sponge habitats on a shelf-depth environment using multibeam sonar and ROV video observations: Learmonth Bank, northern British Columbia, Canada. *Deep Sea Research Part II: Topical Studies in Oceanography* 99: 169–183. <https://doi.org/10.1016/j.dsr2.2013.05.026>
- Rigby, J. K., A. Pisera, T. T. Wrzolek, and G. Racki. 2001. Upper Devonian sponges from the holy cross mountains, central Poland. *Palaeontology* 44: 447–488. <https://doi.org/10.1111/1475-4983.00187>

- Rooper, C. N., K. Williams, A. De Robertis, and V. Tuttle.** 2015. Effect of underwater lighting on observations of density and behavior of rockfish during camera surveys. *Fisheries Research* 172: 157–167. <https://doi.org/10.1016/j.fishres.2015.07.012>
- Strong, M., and P. Lawton.** 2004. URCHIN – manually-deployed geo-referenced video system for underwater reconnaissance and coastal habitat inventory. Technical report of fisheries and aquatic sciences: Fs97-6/2553E. Fisheries and Oceans Canada, St. Andrews, New Brunswick, Canada.
- Tompkins-MacDonald, G. J., and S. P. Leys.** 2008. Glass sponges arrest pumping in response to sediment: implications for the physiology of the hexactinellid conduction system. *Marine Biology* 154: 973–984. <https://doi.org/10.1007/s00227-008-0987-y>
- Vandermeulen, H.** 2007. Drop and towed camera systems for ground-truthing high frequency sidescan in shallow waters. Canadian technical report of fisheries and aquatic sciences 2687. Fisheries and Oceans Canada, Dartmouth, Nova Scotia, Canada.
- Wassenberg, T. J., G. Dews, and S. D. Cook.** 2002. The impact of fish trawls on megabenthos (sponges) on the north-west shelf of Australia. *Fisheries Research* 58: 141–151. [https://doi.org/10.1016/S0165-7836\(01\)00382-4](https://doi.org/10.1016/S0165-7836(01)00382-4)
- Yahel, G., F. Whitney, H. M. Reiswig, D. L. Eerkes-Medrano, and S. P. Leys.** 2007. In situ feeding and metabolism of glass sponges (Hexactinellida, Porifera) studied in a deep temperate fjord with a remotely operated submersible. *Limnology and Oceanography* 52: 428–440. <https://doi.org/10.4319/lo.2007.52.1.0428>
- Ybarra, R.** 2015. Accuracy assessment of depth estimates from variation in pre-and post-processing of multi-beam SONAR surveys in a fjord environment. Undergraduate senior thesis, Washington University, Seattle, Washington, USA.

Received 24 May 2016

Accepted 12 December 2016

Expanded Range Limits of Boreal Birds in the Torngat Mountains of Northern Labrador

DARROCH WHITAKER

Parks Canada, P. O. Box 130, Rocky Harbour, Newfoundland and Labrador A0K 4N0 Canada; email: darroch.whitaker@pc.gc.ca

Whitaker, Darroch. 2017. Expanded range limits of boreal birds in the Torngat Mountains of Northern Labrador. *Canadian Field-Naturalist* 131(1): 55–62. <https://doi.org/10.22621/cfn.v131i1.1957>

The Torngat Mountains lie at the southeastern limit of the Canadian Arctic in northern Labrador, and bird distributions in the region are poorly understood. I visited the Torngat Mountains every summer from 2008 to 2016 and recorded all birds observed. Several boreal bird species were widespread and breeding in the region, representing expansion of known ranges by 100–350 km north along the Labrador coast and 40–90 km east from Ungava Bay. Shrub thickets have expanded dramatically in the Torngat Mountains since the 1980s; thus, these observations may reflect range expansion by boreal birds in response to increased habitat availability.

Key Words: Boreal birds; climate change; Labrador; range shifts; shrubification; Torngat Mountains; treeline

Introduction

Understanding and monitoring the range limits of species can offer important insights into environmental change and valuable information for conservation planning in a changing world. Environmental change is progressing rapidly in northern Canada, particularly along the boreal-arctic ecotone and is evident in the form of both climate change and widespread expansion of shrub communities (“shrubification”; Myers-Smith *et al.* 2011, 2015; IPCC 2014). Many species of birds have also shifted their ranges poleward in North America and Eurasia, a phenomenon that has been linked to climate change, although most such evidence comes from sub-arctic biomes (e.g., Thomas and Lennon 1999; Brommer 2004; Hitch and Leberg 2007; Chen *et al.* 2011). Although atlas projects and citizen science initiatives have provided detailed information on the breeding distribution of bird species throughout much of southern Canada (e.g., Cadman *et al.* 2007), such information across Canada’s North remains limited and imprecise.

As in much of the Arctic, the environment of northern Labrador is changing rapidly. Average air temperature has increased by about 2°C since the early 1990s and is expected to increase by another 2–4°C by 2050 (Allard and Lemay 2012; Finnis 2013; Way and Viau 2014). Coupled with this, growing seasons are becoming longer, with increases of about 20 days forecast by 2050 (He *et al.* 2008; Pouliot *et al.* 2009; Allard and Lemay 2012). These changes have implications for vegetation communities, and both remote sensing and Inuit knowledge indicate that cover of tall shrubs, including willow (*Salix* sp.), alder (*Alnus* sp.), and Dwarf Birch (*Betula glandulosa*), has increased approximately six-fold in the Torngat Mountains of northern Labrador since the 1980s (Parks Canada 2008; Fraser *et al.* 2011; Quirouette and Zorn 2015). Shrubbyfication is occurring

across much of the Arctic (Myers-Smith *et al.* 2011, 2015), but the rate of change is much higher in the Torngat Mountains than in other parts of the Canadian North (Fraser *et al.* 2011; see also Tremblay *et al.* 2012). This may be the result of an interactive functional response of existing shrubs to climate amelioration combined with a large drop in grazing pressure with the decline of the Torngat Mountains Caribou (*Rangifer tarandus*) herd (Wilson *et al.* 2014; Christie *et al.* 2015; Couturier *et al.* 2015).

Studies of bird distributions in northern Labrador have been limited, although a number of ornithologists and naturalists have travelled the region over the past century, and their observations are well documented. Key historical works include those of Austin (1932) and Todd (1963), who report observations from more than 25 expeditions to Labrador and northern Quebec between 1901 and 1958 and also thoroughly review reports from numerous other naturalists who have travelled the region. More recently, Al Veitch spent five seasons at Hebron Fiord (1989–1993) and kept detailed records of his bird observations, which were summarized by Harrington (1994). These records are valuable because they offer detailed information about a seldom-surveyed location near the range limits of many species just before climate and vegetation change accelerated in the region.

From 2008 to 2016, I made annual summer visits to the Torngat Mountains, during which I travelled extensively between Saglek Bay and Seven Islands Bay. The survey area overlapped that of Austin (1932) and Todd (1963) and is 10–20 km north of the area travelled by Veitch (Harrington 1994). During these visits, I recorded information on the distribution and breeding status of all birds observed. Here I compare my observations with documented breeding limits for several species of boreal birds.

Methods

The Torngat Mountains ecoregion (Notzl *et al.* 2013) represents the southeastern limit of the Canadian Arctic Cordillera and spans the northernmost ~300 km of Labrador from Mugford Bay in the south to Killiniq Island in the north (Figure 1). The region is dominated by the Torngat Mountains, with summits exceeding 1500 m, large river valleys, and a complex coast that includes numerous islands, bays, and fiords. Torngat Mountains National Park (9700 km²) was established in 2005 and occupies the northern half of the ecoregion.

The boreal-arctic ecotone (i.e., the “treeline”) in Labrador occurs in the vicinity of Okak (Payette 1983) about 120 km south of the park, and the Torngat Mountains are dominated by arctic vegetation. However, some northern boreal plant communities are found in favourable habitat north of Okak, including small isolated stands of Black Spruce (*Picea mariana* (Mill.) Britton, Sterns & Poggenb.) as far north as Hebron Fiord and a handful of small (i.e., < 1 ha) stands of Balsam Poplar (*Populus balsamifera* L.) and Mountain Ash (*Sorbus americana* Marshall) around Saglek Fiord. Dense 1–4 m tall willow and alder thickets are found in riparian areas and the lower slopes of valleys, but are increasingly sparse in the north and reach a limit near the Eclipse River. To the west in Quebec, conifer stands extend farther north along the George River and in sheltered valleys along the coast of Ungava Bay, reaching a northern limit at Abloviak Fiord (Payette 1983). Black Spruce and Eastern Larch (*Larix laricina* (Du Roi) K. Koch) also extend far inland in the Koroc River Valley, where scattered stands reach a limit near the headwaters of Nakvak Brook (Ouellet 1978; Payette 1983; KRG 2005).

Observations reported here were made during nine years of summer fieldwork in Torngat Mountains National Park (2008–2016), including some made just south of the park. During these visits, I documented all birds observed following an approach similar to that employed in breeding bird atlas studies (e.g., Cadman *et al.* 2007); for each encounter, I recorded species, date, location, and evidence of breeding (Table 1). Although opportunistic, this approach allowed rapid as-

sessment of bird communities at many coastal and inland sites and yielded over 1400 observations of 76 species (data available from eBird [<http://ebird.org/>] or Natureserve [www.natureserve.org] or upon request to D.W.).

However, there were limitations to this approach. Most notably, visits were limited to 3–5 weeks between mid-July and late August each year; thus, it was not possible to observe birds at the peak of breeding in June and early July when they would have been singing and displaying more aggressively. The timing also increased the likelihood of observing post-breeding individuals that may have immigrated from other areas, such as conifer forests along the Ungava coast. Operational constraints limited my travels to the region between Saglek Bay and Kangalaksiorvik Lake, which spans about 100 km at the centre of the Torngat Mountains ecoregion but does not encompass the northernmost ~100 km of Labrador or the ~120 km gap between Saglek and the boreal ecotone near Okak (Figure 1).

Results and Discussion

My observations from 2008 to 2016 indicate that several northern boreal bird species are far more widespread and abundant in the central Torngat Mountains than has been reported previously (Table 2). Further, I found evidence that most of these species are occasionally or regularly breeding 10s to 100s of kilometres north and east of previously reported range limits (Table 2). Admittedly, available historical information on the distribution of these species is incomplete and biased toward more accessible coastal locations. However, it seems implausible that the ornithologists and other naturalists who visited the region over a period of more than 100 years would have consistently missed a whole suite of northern boreal birds. This is especially true given that these species are all found in and around willow and alder thickets that are easily accessed along the coast; because they have the greatest diversity and abundance of birds in the region these thickets would surely have attracted the attention of observers. Thus, it seems likely that the breeding ranges or at least the abundance of several northern boreal birds has increased in the central Torngat Mountains in recent decades.

TABLE 1. Behavioural observations used to assess the breeding status of birds observed in the Torngat Mountains of northern Labrador, 2008–2016.

Breeding status	Behavioural evidence
No evidence of breeding	No behaviour or physical evidence suggestive of breeding
Possible breeding	Seen or heard singing in nesting habitat during breeding period
	Pair seen in nesting habitat
	Territorial nesting behaviour in nesting habitat for > 1 week
	Courtship between male and female
	Visiting possible nest site
Confirmed breeding	Nest building
	Distraction display
	Recently fledged or downy young
	Adult carrying food or fecal sac
	Nest with eggs, egg shells, or young

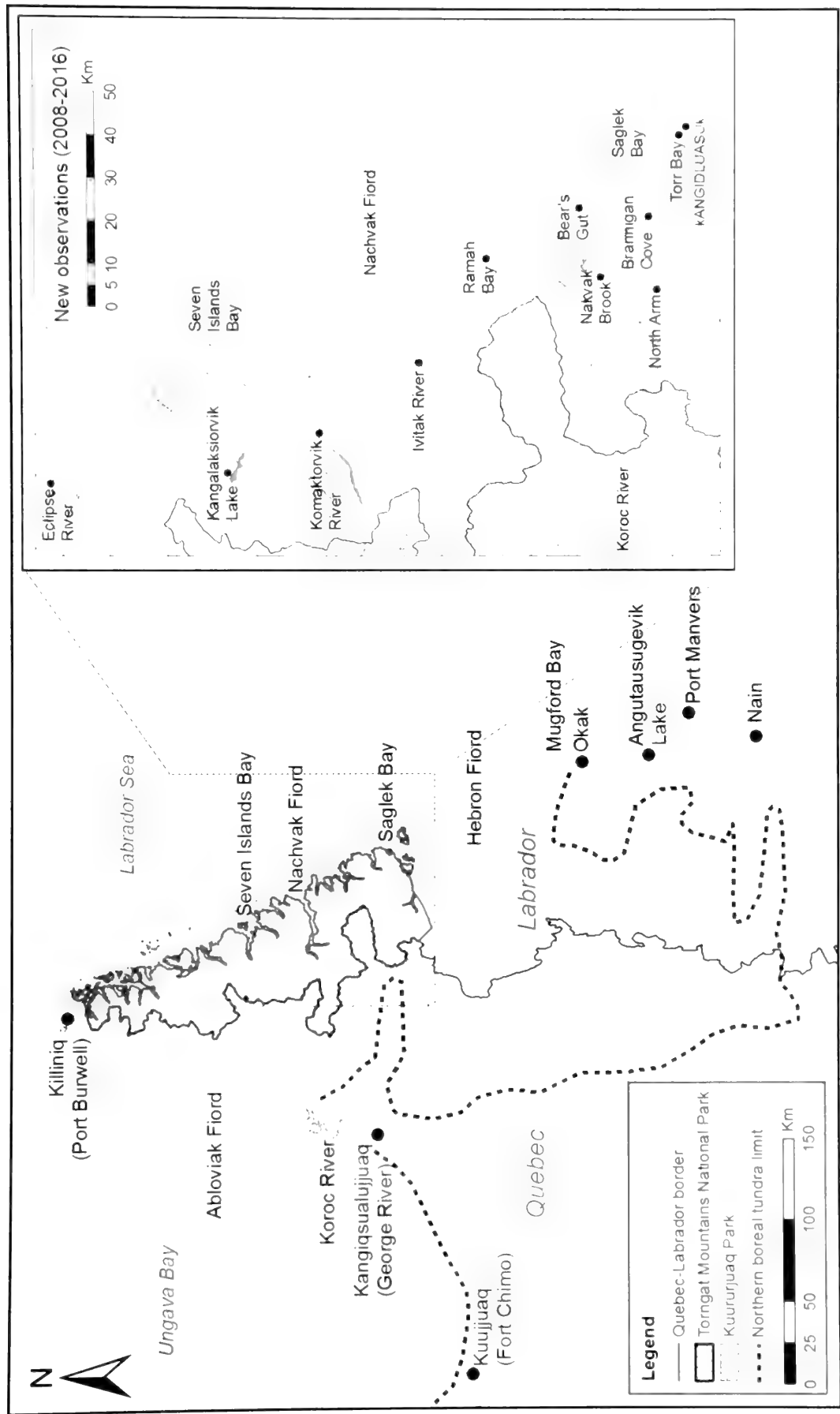


FIGURE 1. Location of the study area in northern Labrador. The dashed line indicates the approximate northern limit of the boreal forest tundra ecozone (from Payette 1983). The inset map depicts the region where new observations were made during July and August, 2008-2016.

TABLE 2. Summary of observations of boreal birds in the Torngat Mountains of Labrador, 2008–2016.

Species	Historical range limits (<i>sources</i> *)	Locations observed (no. observations)	Years observed	Confirmed breeding	Expansion of known breeding range
Spotted Sandpiper (<i>Actitis macularius</i>)	Labrador: Nain and probably Okak (1, 2, 5) NE Quebec: Kuujuaq and Koroc R. (4, 5, 8) Additional sightings from Hebron F., Saglek B., and Abloviak F. (2, 3, 6)	Saglek B. (10; 6 areas) Ramah B. (1) Ivitak R. (3) Komaktorvik F. (1) Kangalaksiorvik L. (4)	2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015	Torr B. (2009) KANGIDLUAJUK (2012) Kangalaksiorvik L. (2015)	230 km NNW of Okak 90 km NNE of Koroc R.
American Robin (<i>Turdus migratorius</i>)	Labrador: Historically Okak (2, 5) but Hebron F. by 1990s (6)	Saglek B. (13; 4 areas) Nakvak Br. (4)	2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016	Torr B. (2008, 2011) Ivitak R. (2012, 2013)	190 km NNW of Okak; 100 km NNW of Hebron F. 50 km NE of Koroc R.
27 observations	NE Quebec: Koroc R. (4, 5, 8)	Ivitak R. (7)			
4 breeding records	Additional sightings from Hebron F. and Nachvak F.; nested at Killiniq in 1920 and 1933 (1, 2)	Komaktorvik R. (1) Kangalaksiorvik L. (2)			
Gray-checked Thrush (<i>Catharus minimus</i>)	Labrador: Okak (2) and possibly to Saglek B. (5, 6)	North Arm (1) Nakvak Br. (1) Ivitak R. (3)	2008, 2009, 2012, 2014	None	
5 observations	NE Quebec: Koroc R. (4, 8)				
Yellow-rumped Warbler (<i>Setophaga coronata</i>)	Labrador: Nain (2, 5); likely breeding at Angutausugevik L. in 1928 (1)	Saglek B. (3; 3 areas) Ivitak R. (3)	2009, 2011, 2012, 2014, 2015, 2016	Ivitak R. (2012)	290 km NNW of Nain; 240 km NNW of Angutausugevik L. 50 km NE of Koroc R.
7 observations	NE Quebec: Koroc R. and south Ungava B. (4, 5, 8)	Kangalaksiorvik L. (1)			
1 breeding record	Additional sightings from Okak and Hebron F. (2, 6)				
Blackpoll Warbler (<i>Setophaga striata</i>)	Labrador: Okak, possibly to Hebron F. (1, 2, 5, 6)	Saglek B. (15; 6 areas) Nakvak Br. (3)	2008, 2009, 2012, 2013, 2014, 2015, 2016	Torr B. (2008, 2016) Brannigan C. (2016) Nakvak Br. (2016) Kangalaksiorvik L. (2015)	230 km NNW of Okak; 160 km NNW of Hebron F. 90 km NNE of Koroc R.; 40 km E of Abloviak F.
33 observations	NE Quebec: Koroc R., possibly to Abloviak F. (3, 4, 5, 8)	Bear's Gut (2) Ivitak R. (9) Kangalaksiorvik L. (4)			
5 breeding records					
Wilson's Warbler (<i>Cardellina pusilla</i>)	Labrador: Makkovik but almost certainly to Nain (1, 2, 5)	Saglek B. (8; 5 areas) Nakvak Br. (1)	2008, 2009, 2011, 2012, 2013, 2014, 2015, 2016	North shore Saglek F. (2015)	350 km NNW of Nain 90 km NNE of Koroc R.; 40 km E of Abloviak F.
20 observations	NE Quebec: Koroc R., possibly to Abloviak F. (3, 4, 5, 8)	Ivitak R. (5) Komaktorvik F. (2) Kangalaksiorvik L. (4)		Brannigan C. (2016) Ivitak R. (2009) Kangalaksiorvik L. (2016)	
4 breeding records					
Northern Waterthrush (<i>Parkesia noveboracensis</i>)	Labrador: Nain and possibly Okak (1, 2, 5, 7) NE Quebec: Koroc R. (2, 4, 5, 8)	Torr B. (2) Nakvak Br. (1)	2013, 2014, 2016	Nakvak Br. (2013)	250 km NNW of Nain; 140 km NNW of Okak 50 km E of Koroc R.
3 observations					
1 breeding record					

TABLE 2 (continued). Summary of observations of boreal birds in the Torngat Mountains of Labrador, 2008–2016.

Species	Historical range limits (sources*)	Locations observed (no. observations)	Years observed	Confirmed breeding	Expansion of known breeding range
Fox Sparrow (<i>Passerella iliaca</i>) 28 observations 3 breeding records	Labrador: Historically Okak, possibly further north (1, 2) and recently to Hebron F. (6) NE Quebec: Koroc R. (2, 5, 8)	Saglek B. (16; 5 areas) Nakvak Br. (1) Bear's Gut (1) Ramah B. (1) Ivitak R. (8) Kangalakstiorvik L. (1)	2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016	Torr B. (2016) Brannigan C. (2016) Ivitak R. (2012)	100 km NNW of Hebron F. 50 km NE of Koroc R.
White-throated Sparrow (<i>Zonotrichia albicollis</i>) 1 observation	Labrador: Lake Melville (2, 5) NE Quebec: Schefferville then rare north along Koksoak R. possibly to Kuujuaq (2, 5, 8)	Brannigan C. (1)	2016	None	
Lincoln's Sparrow (<i>Melospiza lincolni</i>) 1 observation	Labrador: Nain (2, 5) NE Quebec: Kuujuaq (2, 5, 8)	Torr B. (1)	2014	None	
Dark-eyed Junco (<i>Junco hyemalis</i>) 7 observations 1 breeding record	Labrador: Okak but not to Hebron F. (1, 2, 5, 6) NE Quebec: Koroc R. (4, 8)	Saglek B. (3; 3 areas) Nakvak Br. (1) Bear's Gut (1) Ivitak R. (2)	2008, 2011, 2012, 2013, 2014, 2015	Ivitak R. (2012)	190 km NNW of Okak 50 km NE of Koroc R.

Note: B. = Bay; Br. = Brook; C. = Cove; F. = Fiord; L. = Lake; R. = River.
* 1. Austin (1932); 2. Todd (1963); 3. Ouellet (1973); 4. Ouellet (1978); 5. Godfrey (1986); 6. Veitch, reported in Harrington (1994); 7. Whitaker and Eaton (2014); 8. Quebec Breeding Bird Atlas (2016).

Some of these species are well established and widespread in suitable habitat (Spotted Sandpiper [*Actitis macularius*], American Robin [*Turdus migratorius*], Blackpoll Warbler [*Setophaga striata*], Wilson's Warbler [*Cardellina pusilla*], Fox Sparrow [*Passerella iliaca*]), while others were infrequently observed (Gray-checked Thrush [*Catharus minimus*], Yellow-rumped Warbler [*Setophaga coronata*], Northern Waterthrush [*Parkesia noveboracensis*], Dark-eyed Junco [*Junco hyemalis*]). Lincoln's Sparrow (*Melospiza lincolni*) and White-throated Sparrow (*Zonotrichia albicollis*) are more southern species that were only seen once and, thus, were likely vagrants.

Although several studies have shown that many bird species are shifting their ranges poleward, this process does not appear to be directly constrained by ambient temperature, as most tolerate colder temperatures in their breeding range than occur at their poleward range limit (Coristine and Kerr 2015). Rather, range limits may be constrained by composite climatic factors, lags in the expansion of plant communities that afford appropriate breeding and foraging habitat, geographic barriers, competition, and intrinsic life history traits (Batesman *et al.* 2015; Coristine and Kerr 2015; Stralberg *et al. in press*). With the exception of Spotted Sandpipers, which were seen primarily along shorelines, the boreal birds I encountered were most often found in and around low-lying willow and alder thickets. American Robins, Fox Sparrows, and Dark-eyed Juncos were somewhat more catholic, also making regular use of Dwarf Birch thickets and other tundra shrub habitats and occurring in both low-lying areas and on the mid-slopes of valleys and fiords. Thus, it seems likely that expansion of boreal birds in the central Torngat Mountains has been facilitated by the recent rapid expansion of tall shrub habitats in the region. Such shrubification is becoming widespread in the Arctic, albeit typically at a much slower rate, so a similar trend of increasing habitat availability for many northern boreal and Taiga bird species is expected throughout the North (Sokolov *et al.* 2012; Henden *et al.* 2013; Boelman *et al.* 2015; Mizel *et al.* 2016). Given their high mobility, birds are physically capable of rapidly tracking expansion of suitable breeding habitat, and, consistent with Stralberg *et al. (in press)*, my observations suggest that mountainous terrain *per se* has not hindered this process in northern Labrador. Indeed, I regularly found several boreal birds in small riparian shrub thickets in isolated river valleys separated by large bays and fiords and highlands exceeding 1000 m.

Future changes in bird communities of the Torngat Mountains are difficult to predict and will depend on the habitat needs of individual species (Thompson *et al.* 2016). A number of conifer-associated boreal birds (e.g., Spruce Grouse [*Falcipennis canadensis*], Gray Jay [*Perisoreus canadensis*], and Boreal Chickadee [*Poecile hudsonicus*]) also breed along the Koroc River (Ouellet 1978; Québec Breeding Bird Atlas 2016).

However, expansion of such species into northern Labrador seems improbable unless conifers spread into the region first, a process that may take many decades if it occurs at all. It is also unclear whether the species I observed in the central Torngat Mountains could eventually occupy the entire Ungava Peninsula. The shrub expansion that has been documented to date is most pronounced in the southern and central Torngat Mountains (Fraser *et al.* 2011; Quirouette and Zorn 2015), and well developed shrub tickets are rare north of the Eclipse River. Thus, shrubification in the northernmost Torngat Mountains may be increasingly constrained by plant dispersal rather than simple infilling and growth of existing shrubs and, as a result, may proceed at a slower rate (Myers-Smith *et al.* 2011, 2015). Further, if the Caribou herd in the Torngat Mountains recovers and grazing pressure returns to past levels, then shrubs may once again become suppressed, with negative consequences for any associated bird species (e.g., Ims and Henden 2012; Henden *et al.* 2013; Christie *et al.* 2015).

Acknowledgements

Observations reported here include some made with or reported by other Parks Canada staff, bear monitors from Torngat Mountains Base Camp and Research Station, participants in the kANGIDLUASUK Student Program and other researchers. In particular these include Dorothy Agnatok, Andrew Andersen, Joe Atsatata, Geoff Goodyear, Elias Harris, Robert Harris, Harry Hay, Luise Hermanutz, Brandon Holden, Rodd Laing, Martin Lougheed, Donald McLennan, Boonie Merkuratsuk, Eli Merkuratsuk, Jacko Meruratsuk, John Merkuratsuk, Jobie Unatweenuk, and Stephen Woodley. Finally Michel Gosselin of the Canadian Museum of Nature kindly shared Henri Ouellet's field notes and reports from Ungava Bay. This work is dedicated to Dorothy Agnatok, who's memory will forever be a part of the landscape of the Torngat Mountains for me and the many other people she touched.

Literature Cited

- Allard, M., and M. Lemay. 2012. Nunavik and Nunatsiavut: from science to policy, an Integrated Regional Impact Study (IRIS) of climate change and modernization. ArcticNet Inc., Québec, Quebec, Canada.
- Austin, O. L. 1932. The Birds of Newfoundland Labrador. Memoirs of the Nuttall Ornithological Club, no. VII. Nuttall Ornithological Club, Cambridge, Massachusetts, USA.
- Batesman, B. L., A. M. Pidgeon, V. C. Radeloff, J. VanDerWal, W. E. Thogmartin, S. J. Vavrus, and P. J. Heglund. 2015. The pace of past climate change vs. potential bird distributions and land use in the United States. *Global Change Biology* 22: 1130–1144. <https://doi.org/10.1111/gcb.13154>
- Boelman, N. T., L. Gough, J. Wingfield, S. Goetz, A. Asmus, H. E. Chmura, J. S. Krause, J. H. Perez, S. K. Sweet, and K. C. Guay. 2015. Greater shrub dominance alters breeding habitat and food resources for migratory songbirds in Alaskan arctic tundra. *Global Change Biology* 21: 1508–1520. <https://doi.org/10.1111/gcb.12761>

- Brommer, J. E.** 2004. The range margins of northern birds shift polewards. *Annales Zoologici Fennici* 41: 391–397.
- Cadman, M. D., D. A. Sutherland, G. G. Beck, D. Lepage, and A. R. Couturier.** 2007. Atlas of the Breeding Birds of Ontario, 2001–2005. Bird Studies Canada, Environment Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources, and Ontario Nature, Toronto, Ontario, Canada.
- Chen, I. C., J. K. Hill, R. Ohlemuller, D. B. Roy, and C. D. Thomas.** 2011. Rapid range shifts of species associated with high levels of climate warming. *Science* 333: 1024–1026. <https://doi.org/10.1126/science.1206432>
- Christie, K. S., J. P. Bryant, L. Gough, V. T. Ravolainen, R. W. Ruess, and K. D. Tape.** 2015. The role of vertebrate herbivores in regulating shrub expansion in the Arctic: a synthesis. *BioScience* 65: 1123–1133. <https://doi.org/10.1093/biosci/biv137>
- Coristine, L. E., and J. T. Kerr.** 2015. Temperature-related geographical shifts among passerines: contrasting processes along poleward and equatorward range margins. *Ecology and Evolution* 5: 5162–5176. <https://doi.org/10.1002/ece3.1683>
- Couturier, S., A. Dale, J. Mitchell Foley, J. Snook, and B. Wood.** 2015. First scientific data on herd size and population dynamics of the Torngat Mountains caribou herd. Technical report. Torngat Wildlife, Plants and Fisheries Secretariat, Happy Valley Goose Bay, Newfoundland and Labrador, Canada. <https://doi.org/10.13140/RG.2.1.3213.1043>
- Finnis, J.** 2013. Predicted impacts of climate change on the province of Newfoundland and Labrador. Report to the Newfoundland and Labrador Office of Climate Change, Energy Efficiency and Emissions Trading. Department of Geography, Memorial University, St. John's, St. John's, Newfoundland and Labrador, Canada.
- Fraser, R. H., I. Olthof, M. Carrier, A. Deschamps, and D. Pouliot.** 2011. Detecting long-term changes to vegetation in northern Canada using the Landsat satellite image archive. *Environmental Research Letters* 6: 045502. <https://doi.org/10.1088/1748-9326/6/4/045502>
- Godfrey, W. E.** 1986. The Birds of Canada (revised edition). National Museums of Canada, Ottawa, Ontario, Canada.
- Harrington, F. H.** 1994. Fauna of the Torngat Mountains area. Unpublished report to Parks Canada. Mount Saint Vincent University, Halifax, Nova Scotia, Canada.
- He, Y., X. Guo, P. Dixon, and J. Wilmshurst.** 2008. Satellite monitoring of northern ecosystems using multi-sensors. Unpublished report to Parks Canada. Department of Geography, University of Saskatchewan, and Western and Northern Canada Service Centre, Parks Canada, Winnipeg, Manitoba, Canada.
- Henden, J. A., N. G. Yoccoz, R. A. Ims, and K. Langeland.** 2013. How spatial variation in areal extent and configuration of labile vegetation states affect the riparian bird community in Arctic tundra. *PLoS ONE* 8: e63312. <https://doi.org/10.1371/journal.pone.0063312>
- Hitch, A. T., and P. L. Leberg.** 2007. Breeding distributions of North American bird species moving north as a result of climate change. *Conservation Biology* 21: 534–539. <https://doi.org/10.1111/j.1523-1739.2006.00609.x>
- Ims, R. A., and J. A. Henden.** 2012. Collapse of an Arctic bird community resulting from ungulate-induced loss of erect shrubs. *Biological Conservation* 149: 2–5. <https://doi.org/10.1016/j.biocon.2012.02.008>
- IPCC (Intergovernmental Panel on Climate Change).** 2014. Climate change 2014: synthesis report. IPCC, Geneva, Switzerland.
- KRG.** 2005. Kuururjuaq park project (Monts-Torngat-et-Rivière Koroc): status report. Kativik Regional Government, Renewable Resources, Environmental and Land Use Planning Department, Kuururjuaq, Quebec, Canada. Accessed 25 April 2016. <http://docs.nunavikparks.ca/SiteCollectionDocuments/EN/Kuururjuaq/StatusReport.pdf>.
- Mizel, J. D., J. H. Schmidt, C. L. McIntyre, and C. A. Roland.** 2016. Rapidly shifting elevational distributions of passerine species parallel vegetation change in the subarctic. *Ecosphere* 7: e01264. <https://doi.org/10.1002/ecs2.1264>
- Myers-Smith, I. H., B. C. Forbes, M. Wilmking, M. Hallinger, T. Lantz, D. Blok, K. D. Tape, M. Macias-Fauria, U. Sass-Klaassen, E. Lévesque, S. Boudreau, P. Ropars, L. Hermanutz, A. Trant, L. Siegwart Collier, S. Weijers, J. Rozema, S. A. Rayback, N. M. Schmidt, G. Schaepman-Strub, S. Wipf, C. Rixen, C. B. Ménard, S. Venn, S. Goetz, L. Andreu-Hayles, S. Elmendorf, V. Ravolainen, J. Welker, P. Grogan, H. E. Epstein, and D. S. Hik.** 2011. Shrub expansion in tundra ecosystems: dynamics, impacts and research priorities. *Environmental Research Letters* 6: 045509. <https://doi.org/10.1088/1748-9326/6/4/045509>
- Myers-Smith, I. H., S. C. Elmendorf, P. S. A. Beck, M. Wilmking, M. Hallinger, D. Blok, K. D. Tape, S. A. Rayback, M. Macias-Fauria, B. C. Forbes, J. D. M. Speed, N. Boulanger-Lapointe, C. Rixen, E. Lévesque, N. M. Schmidt, C. Baittinger, A. J. Trant, L. Hermanutz, L. Siegwart Collier, M. A. Dawes, T. C. Lantz, S. Weijers, R. H. Jørgensen, A. Buchwal, A. Buras, A. T. Naito, V. Ravolainen, G. Schaepman-Strub, J. A. Wheeler, S. Wipf, K. C. Guay, D. S. Hik, and M. Vellend.** 2015. Climate sensitivity of shrub growth across the tundra biome. *Nature Climate Change* 5: 887–891. <https://doi.org/10.1038/nclimate2697>
- Notzl, L., R. Greene, and J. L. Riley.** 2013. Labrador Nature Atlas, Volume two: ecozones, ecoregions and ecodistricts. Nature Conservancy of Canada, Toronto, Ontario, Canada.
- Ouellet, H.** 1973. List of birds recorded at two localities on the east coast of Ungava Bay, Quebec, in June and July 1973. Unpublished report. National Museum of Canada, Ottawa, Ontario, Canada.
- Ouellet, H.** 1978. La vallée de la rivière Korok, une enclave forestière en toundra québécoise. *Nord* 25: 6–11.
- Parks Canada.** 2008. State of park report, Torngat Mountains National Park of Canada. Unpublished report. Parks Canada, Rocky Harbour, Newfoundland and Labrador, Canada.
- Payette, S.** 1983. The forest tundra and present tree lines of the northern Québec-Labrador Peninsula. *Nordica* 47: 3–23.
- Pouliot, D., R. Latifovic, and I. Olthof.** 2009. Trends in vegetation NDVI from 1 km AVHRR data over Canada for the period 1985–2006. *International Journal of Remote Sensing* 30: 149–168. <https://doi.org/10.1080/01431160802302090>
- Québec Breeding Bird Atlas.** 2016. Atlas of the breeding birds of Québec, 2010–2014. Regroupement Québec Oiseaux, Environment and Climate Change Canada, and Bird Studies Canada, Québec, Quebec, Canada. Accessed 25 April 2016. http://www.atlas-oiseaux.qc.ca/index_en.jsp.
- Quirouette, J., and P. Zorn.** 2015. Subtle vegetation change Torngat Mountains. Unpublished report. Parks Canada, Gatineau, Quebec, Canada.

- Sokolov, V., D. Ehrich, N. G. Yoccoz, A. Sokolov, and N. Lecomte.** 2012. Bird communities of the arctic shrub tundra of Yamal: habitat specialists and generalists. *PLoS ONE* 7: e50335. <https://doi.org/10.1371/journal.pone.0050335>
- Stralberg, D., S. M. Matsuoka, C. M. Handel, F. K. A. Schmiegelow, A. Hamann, and E. M. Bayne.** *In press*. Biogeography of boreal passerine range dynamics in western North America: past, present, and future. *Ecography*. <https://doi.org/10.1111/ecog.02393>
- Thomas, C. D., and J. J. Lennon.** 1999. Birds extend their ranges northwards. *Nature* 399: 213. <https://doi.org/10.1038/20335>
- Thompson, S. J., C. M. Handel, R. M. Richardson, and L. B. McNew.** 2016. When winners become losers: predicted nonlinear responses of Arctic birds to increasing woody vegetation. *PLoS ONE* 11: e0164755. <https://doi.org/10.1371/journal.pone.0164755>
- Todd, W. E. C.** 1963. *Birds of the Labrador Peninsula*. Carnegie Museum and University of Toronto Press, Toronto, Ontario, Canada.
- Tremblay, B., E. Lévesque, and S. Boudreau.** 2012. Recent expansion of erect shrubs in the Low Arctic: evidence from eastern Nunavik. *Environmental Research Letters* 7: 035501. <https://doi.org/10.1088/1748-9326/7/3/035501>
- Way, R. G., and A. E. Viau.** 2014. Natural and forced air temperature variability in the Labrador region of Canada during the past century. *Theoretical and Applied Climatology* 121: 413–424. <https://doi.org/10.1007/s00704-014-1248-2>
- Whitaker, D. M., and S. W. Eaton.** 2014. Northern Waterthrush (*Parus noveboracensis*). In *The Birds of North America Online*. Edited by A. Poole. Cornell Laboratory of Ornithology, Ithaca, New York, USA. <https://doi.org/10.2173/bna.182>
- Wilson, K. S., M. W. Basterfield, C. Furgal, T. Sheldon, E. Allen, the communities of Nain and Kangiqsualujjuaq, and The Co-operative Management Board for the Torngat Mountains National Park.** 2014. Torngat Mountains caribou herd Inuit knowledge, culture and values study. Final report to Nunatsiavut government. Makivik Corporation, Parks Canada, and the Torngat Wildlife and Plants Co-Management Board, Nain, Newfoundland and Labrador, Canada.

Received 26 April 2016

Accepted 28 March 2017

European Skipper Butterfly (*Thymelicus lineola*) Associated with Reduced Seed Development of Showy Lady's-slipper Orchid (*Cypripedium reginae*)

PETER W. HALL^{1, 5}, PAUL M. CATLING², PAUL L. MOSQUIN³, and TED MOSQUIN⁴

¹24 Wendover Avenue, Ottawa, Ontario K1S 4Z7 Canada

²170 Sanford Avenue, Ottawa, Ontario K2C 0E9 Canada

³Research Triangle International, 3040 East Cornwallis Road, P.O. Box 12194, Raleigh, North Carolina 27709-2194 USA

⁴3944 McDonalds Corners Road, Balderson, Ontario K0G 1A0 Canada

⁵Corresponding author: halljp@rogers.com

Hall, Peter W., Paul M. Catling, Paul L. Mosquin, and Ted Mosquin. 2017. European Skipper butterfly (*Thymelicus lineola*) associated with reduced seed development of Showy Lady's-slipper orchid (*Cypripedium reginae*). *Canadian Field-Naturalist* 131(1): 63–68. <https://doi.org/10.22621/cfn.v131i1.1952>

It has been suggested that European Skipper butterflies (*Thymelicus lineola*) trapped in the lips of the Showy Lady's-slipper orchid (*Cypripedium reginae*) may interfere with pollination. This could occur through blockage of the pollinator pathway, facilitation of pollinator escape without pollination, and/or disturbance of the normal pollinators. A large population of the orchid at an Ottawa Valley site provided an opportunity to test the interference hypothesis. The number of trapped skippers was compared in 475 post-blooming flowers with regard to capsule development and thus seed development. The presence of any skippers within flowers was associated with reduced capsule development ($P = 0.0075$), and the probability of capsule development was found to decrease with increasing numbers of skippers ($P = 0.0271$). The extent of a negative effect will depend on the abundance of the butterflies and the coincidence of flowering time and other factors. Counts of skippers trapped in flowers were found to follow closely a negative binomial distribution ($P = 0.8656$).

Key Words: *Cypripedium reginae*; *Thymelicus lineola*; Showy Lady's-slipper; orchid; European Skipper; butterfly; pollination; pollinator interference; negative binomial distribution; Ottawa Valley

Introduction

The potential for pollination interference by European Skippers (*Thymelicus lineola* Oechsenheimer) caught in the lips of Showy Lady's-slippers (*Cypripedium reginae* Walter), has been alluded to by a number of authors (e.g., Catling 1974; Barrows 1983; Vogt 1990) and repeated with additional references by Argue (2012). The usual pollinators are leaf-cutter bees (*Megachile* spp.) and syrphid flies (*Syrphus* spp.), which enter the slipper-shaped lip but cannot exit the same way as a result of its inflexed margin (Argue 2012). They first have to pass the stigma, where they deposit any pollen they are carrying and then exit by one of two openings at the base of the lip where they receive a new load of pollen on the thorax.

The flowers attract insects by a combination of odour and colour (white and pink, with pink nectar guides), but there is no nectar reward, as with other species in the genus, which are also deceptive (e.g., Argue 2012). Escape of skipper butterflies entering the lip is prevented by the inflexed margin; they are also unable to escape through the basal openings, as they are too delicate and high, with their wings closed over the top of the body. Entrapment of skippers may lead to reduced pollination by disturbance of the normal pollinators; possible mechanisms include blocking the pathway and/or facilitating pollinator escape without pollination. The effect may be substantial: Vogt (1990) found skippers in about a third of the flowers at his Vermont site. Barrows

(1983) and Catling (1974) reported skippers in about half of 100 flowers at several Ontario sites.

The European Skipper was first introduced to North America in 1910 (Hall *et al.* 2014), so it has likely not evolved in the presence of the deceptive orchid flower, which might have led to avoidance. The European Skipper is now one of the most abundant butterflies in North America.

At Purdon Fen (44.99260°N, 76.54596°W) near Lanark in eastern Ontario, we had an unusual opportunity to evaluate the impact of the European Skipper butterfly on capsule (and seed) development of the Showy Lady's-slipper orchid. This orchid has an extensive distribution in northeastern North America (Luer 1975), but there are few, if any, locations where it is as abundant as at the Purdon site where the total population of stems within 1.2 ha has fluctuated between 15 735 in 1985 (Mosquin 1986) and 7367 in 2015 (Ross Fergusson, personal communication). In 2015, the skippers, which generally frequent open country, were much more abundant than usual in the wooded area surrounding the fen and had entered the wooded fen where the orchids occur.

This area is a semi-open Eastern White Cedar (*Thuja occidentalis* L.) woodland with an understory dominated by Tussock Sedge (*Carex stricta* Lam.). During a visit to the site on 17 June 2015, we saw at least 300 skippers in 30 minutes, flying within the orchid colony, and some were trapped in the flowers (Figure 1). By

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalists' Club.

10 July, the flowers had turned brown with development of ovaries into capsules or had more or less withered. The former had been pollinated but the latter had not (Figure 2). Because most flowers had not completely deteriorated, it was possible to open the brown lips and note the presence of skippers and count them (Figure

3). This we did to test the hypothesis that the presence of any skippers was deleterious, and the more skippers there were in a flower, the greater the likelihood of interference and the lower the likelihood of capsule development.



FIGURE 1. Fresh Showy Lady's-slipper (*Cypripedium reginae*) flower with one European Skipper (*Thymelicus lineola*) trapped inside and one trying to enter the flower, Purdon Fen, eastern Ontario, 2015. Photo: Peter W. Hall.



FIGURE 2. Shrivelled Showy Lady's-slipper (*Cypripedium reginae*) flowers, one with developed (right) and one with undeveloped capsule, Purdon Fen, eastern Ontario, 2015. Photo: Peter W. Hall.



FIGURE 3. Opened shrivelled Showy Lady’s-slipper (*Cypripedium reginae*) flower with seven trapped European Skippers (*Thymelicus lineola*), Purdon Fen, eastern Ontario, 2015. Photo: Peter W. Hall.

Methods

Purdon Fen is protected and managed by the Mississippi Valley Conservation Authority (MVCA). We obtained permission to gather data; MVCA has shown much interest over two decades in accumulating information that would help to inform management (Mosquin and Brown 2006).

We sampled 475 flowers in an extensive area accessible from the boardwalk and considered to be representative of the entire colony. Within this area, we selected flower stalks approximately 1 m apart. This area included flowers that opened before the peak abundance of skippers as well as those that opened after. We avoided a small area where hand pollinations had been done to increase fecundity. We examined flowers and scored capsules as developed, partly developed, or completely undeveloped (with empty brown shrivelled capsules). For statistical purposes, we compared numbers of undeveloped capsules with the combined total of fully and partly developed capsules.

Each flower was opened and the number of skippers inside counted. We also examined 100 undamaged individual skippers to determine their sex and whether they

carried any lady’s-slipper pollen. Males were distinguished by a characteristic (but sometimes inconspicuous) horizontal black stigma on the forewing.

Our main study hypothesis — that there was less capsule development with skippers present and less with more skippers — was tested statistically using tests of proportions and logit modeling. Also of interest was the possibility of gender bias among counted skippers, which was tested via a one-sample test of proportions. We also considered the distribution of numbers of skippers within flowers and whether it followed either a Poisson or negative binomial model.

All statistical analyses were performed using the R statistical computing language (R Core Team 2015). The packages MASS (Venables and Ripley 2002) and binom (Dorai-Raj 2014) were used for maximum likelihood estimation of the negative binomial distribution and to calculate Bayesian credible intervals, respectively.

Results

Of 475 flowers examined, 398 (83.8%) had no capsule development and 77 (16.2%) had partly to fully

developed capsules. Members of each group with various numbers of trapped skippers are indicated in Table 1. Of the plants with no skippers trapped in flowers, 24.3% had developed capsules, compared with plants where skippers were present, of which 13.9% had developed capsules. A two-sample test of equality of proportion of developed capsules for plants both with and without skippers present was rejected in favour of the alternative that this proportion was less when skippers were present ($P = 0.0075$). A logit model of the probability of capsule development, with number of skippers as the covariate, showed a significant effect for number of skippers ($P = 0.0271$; one-sided because our alternative hypothesis was directional; we tested

Table 1. Number of European Skippers (*Thymelicus lineola*) in developed and non-developed capsules of Showy Lady's-slippers (*Cypripedium reginae*) at Purdon Fen near Lanark, eastern Ontario in 2015.

No. skippers	Capsule not developed	Capsule developed
0	81	26
1	104	24
2	85	9
3	57	10
4	33	1
5	23	3
6	7	2
7	4	0
8	2	1
9	1	0
10	0	1
11	0	0
12	1	0

the null hypothesis of no effect of skipper number versus the alternative of a detrimental effect). The probability of capsule development decreased with number of skippers (estimated logit model parameters: intercept -1.37 , slope -0.152). Model-predicted probabilities are plotted in Figure 4, together with sample estimates and their associated 95% Bayesian credible intervals (Jeffrey's prior) as a measure of their uncertainty.

Considering only the counts of skippers trapped in flowers, we tested the hypothesis that the total count (Table 1) follows a Poisson distribution. This would happen if the rate of entrapment was constant and did not depend on the number of skippers already trapped and if all flowers were exposed to skippers for equal amounts of time. After collapsing skipper counts of seven or larger because of small expected values, a goodness-of-fit test ($P < 0.0001$; likelihood ratio) rejected this simple model.

In our sample, the mean number of skippers per flower was 1.94 with a variance of 3.28; thus, skippers were over-dispersed relative to the Poisson distribution, which requires mean and variance to be equal. A common model for over-dispersed count data is the two-parameter negative binomial distribution. Maximum likelihood estimation of its parameters gave a mean of 1.94 and a dispersion parameter of 2.87. After collapsing skipper counts of nine or more because of small expected values, goodness-of-fit testing did not reject this model ($P = 0.8656$; likelihood ratio), but instead resulted in a very close fit to these data. A frequency distribution of the observed skipper counts together with Poisson and negative binomial fitted values is provided in Figure 5.

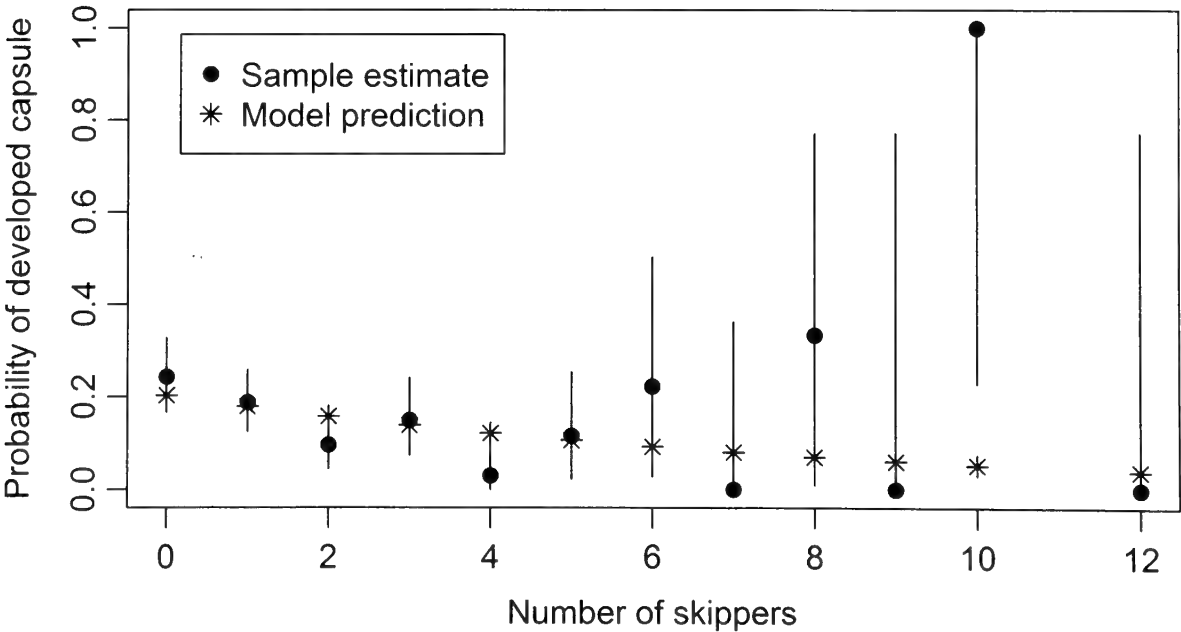


FIGURE 4. Model-predicted probability of capsule development in Showy Lady's-slipper (*Cypripedium reginae*) depending on the number of entrapped European Skippers (*Thymelicus lineola*).

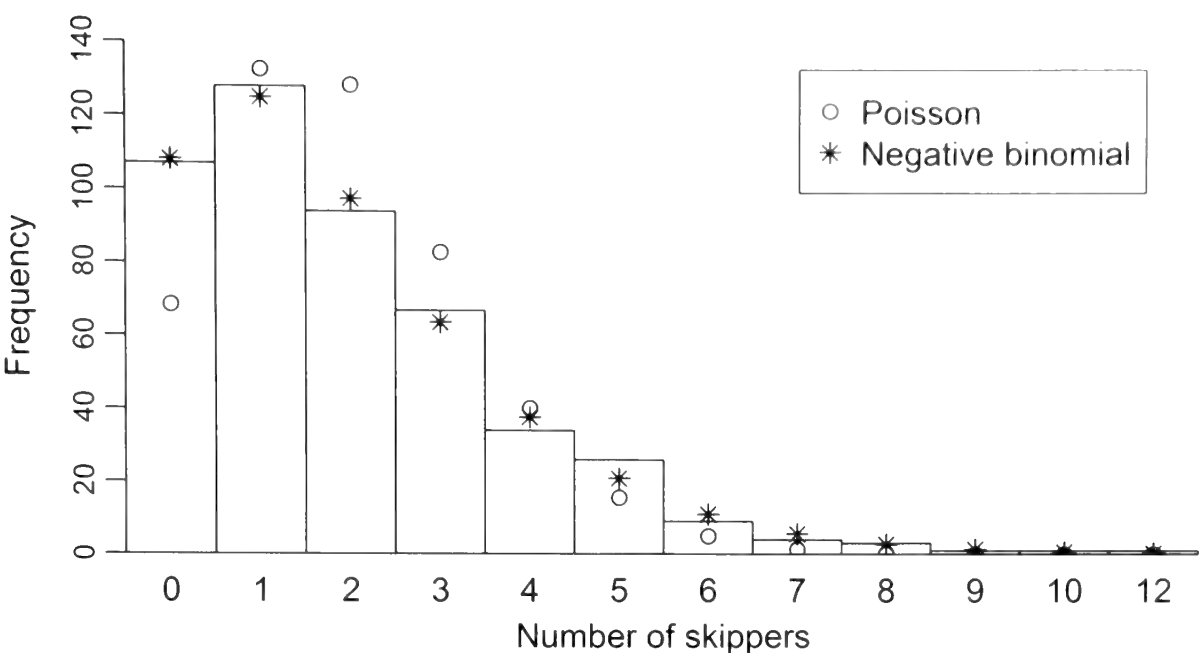


FIGURE 5. Distribution of the observed number of European Skippers (*Thymelicus lineola*) trapped in Showy Lady's-slippers (*Cypripedium reginae*), showing both fitted-model Poisson and negative binomial model counts.

Of the sample of 100 trapped skippers with an undamaged upper forewing, 92 were males and the difference in proportion of sexes was highly significant ($P < 0.0001$). Only three of 100 butterflies carried anything that looked like a pollen smear. In each case, it was on the smooth surface (by complete loss of scales) of the dorsal thorax, and microscopic examination revealed it to be stigmatic tissue. Only one monad characteristic of *Cypripedium* pollen was seen.

Discussion

In this paper, we have shown that capsule development in Showy Lady's-slipper orchids at Purdon Fen in spring 2015 was decreased when European Skipper butterflies were trapped inside the flowers and, also, that the probability of development decreased with the number of skippers trapped. We have also shown that the distribution of trapped skippers closely followed a negative binomial distribution and that there was strong gender bias in entrapment, males being predominant.

The 16.2% of orchids with capsule development in 2015 is smaller than the 22.7% with capsule development recorded at the study site by Mosquin in 1985 (Mosquin 1986: 42, Table 3). However, this decline should not necessarily be attributed to interference by skippers, because many factors can account for differences in fecundity from year to year, such as late frosts killing pollinators and/or flowers and population sizes of pollinators. We note, however, that the percentage of orchids with developed capsules, which had no entrapped skippers, was 24%; thus, the 1985 percentage, being slightly smaller than this, might be achievable in

a year with very few skippers. In 2015, there was an unusually high population of European Skippers in the area, as determined by qualitative observations, so, they might have had a higher than normal impact on capsule development. Comparisons with other years could be an interesting follow-up study.

The idea that productivity in 2015 might be compared with that of past years when skippers were likely less abundant is of interest, but constrained by a lack of historical data and by a lack of information on many factors that might affect seed development from year to year. If additional risk factors are proposed, then the logit modeling in this paper could be extended.

We considered the possibility that an entrapped skipper could encounter an anther in its attempts to escape and then transfer pollen to the stigmatic surface of the same flower. This could lead to an expanded ovary with seeds. However, we have no evidence of this happening based on examination of the surfaces of trapped skippers for a pollen smear. The single monad found may have been left on the stigma by an earlier pollinating bee and then rubbed by the skipper onto its thorax. The results of the data analysis also argue against regular within-flower pollen transfer because the deleterious effect on pollination increases with the number of trapped skippers, whereas it would likely decrease with increased trapped skippers available to transfer pollen if there was within-flower pollen transfer.

Because skipper counts were negatively associated with capsule development, we examined their distribution and found the number of trapped skippers to follow a negative binomial distribution very closely. A well-

known property of this distribution is that it is equivalent to the counts being Poisson distributed with rate parameter randomly distributed according to a gamma distribution. Thus, if this decomposition is valid for the Showy Lady's-slipper, skipper counts are Poisson distributed at a flower-varying rate. Future analyses of counts may be amenable to Poisson or negative binomial regression analysis, if potential explanatory factors can be identified.

We found an extreme gender bias toward males among entrapped skippers. The likely explanation, although not sustainable by evidence in this case, is that males of most butterflies emerge before females and more likely overlap with the peak lady's-slipper flowering period.

This work is the first to associate European Skipper butterflies with a negative impact on capsule and, therefore, seed production in the Showy Lady's-slipper orchid. It is also the first time that the potential importance of this phenomenon has been suggested because of the widespread occurrence of trapped skippers.

Acknowledgements

We thank Jeremy Aldworth for helpful comments on a draft of this paper. We also thank Ross Fergusson, Mississippi Valley Conservation Authority, for his estimate of the number of orchids at Purdon Fen in 2015.

Literature Cited

Argue, C. L. 2012. *The Pollination Biology of North American Orchids*. Volume 1. Springer, New York, New York, USA. <https://doi.org/10.1007/978-1-4614-0592-4>

- Barrows, E. M.** 1983. *Cypripedium* flowers entrap adult *Thymelicus lineola* (Lepidoptera: Hesperidae) in northern Michigan. *Journal of the Lepidopterists' Society* 37: 265–268.
- Catling, P. M.** 1974. A butterfly-trapping orchid. *Michigan Entomological Society Newsletter* 19: 1–3.
- Dorai-Raj, S.** 2014. binom: binomial confidence intervals for several parameterizations. R package version 1.1-1. Accessed 30 January 2017. <http://CRAN.R-project.org/package=binom>.
- Hall, P. W., C. D. Jones, A. E. Guidotti, and B. Hubley.** 2014. *The ROM Field Guide to Butterflies of Ontario*. Royal Ontario Museum Press, Toronto, Ontario, Canada.
- R Core Team.** 2015. R: A language and environment for statistical computing. Version 3.2.2. R Foundation for Statistical Computing, Vienna, Austria. Accessed 10 December 2015. <https://www.R-project.org/>.
- Mosquin, T.** 1986. A management plan for the Showy Lady-slipper *Cypripedium reginae*, in the Purdon Conservation Area, Lanark County, Ontario. Part I: final report. Mississippi Valley Conservation Authority, Lanark, Ontario, Canada.
- Mosquin, T., and L. Brown.** 2006. A new management plan for the Showy Lady-slipper, *Cypripedium reginae*, in Purdon Conservation Area, Lanark County, Ontario. Final report. Mississippi Valley Conservation Foundation. Lanark, Ontario, Canada.
- Venables, W. N., and B. D. Ripley.** 2002. *Modern Applied Statistics with S*. Fourth edition. Springer, New York, USA. <https://doi.org/10.1007/978-0-387-21706-2>
- Vogt, C. A.** 1990. Pollination in *Cypripedium reginae*. *Lindleyana* 5: 145–150.

Received 10 October 2015

Accepted 3 February 2017

A First Count of Thick-billed Murres (*Uria lomvia*) and Black-legged Kittiwakes (*Rissa tridactyla*) Breeding on Bylot Island

ANTHONY J. GASTON^{1,4}, MARC-ANDRÉ CYR², and KIERAN O'DONOVAN³

¹Science and Technology Branch, Environment and Climate Change Canada, Carleton University, Ottawa, Ontario K1A 0H3 Canada

²Canadian Wildlife Service, Environment and Climate Change Canada, Place Vincent Massey, 351 St. Joseph Boulevard, Gatineau, Quebec K1A 0H3 Canada

³308a Klukshu Avenue, Whitehorse, Yukon Y1A 3Y1 Canada

⁴Corresponding author: tonygastonconsult@gmail.com

Gaston, Anthony J., Marc-André Cyr, and Kieran O'Donovan. 2017. A first count of Thick-billed Murres (*Uria lomvia*) and Black-legged Kittiwakes (*Rissa tridactyla*) breeding on Bylot Island. *Canadian Field-Naturalist* 131(1): 69–74. <https://doi.org/10.22621/cfn.v131i1.1953>

Bylot Island, part of Sirmilik National Park, supports two major breeding colonies of intermingled Thick-billed Murres (*Uria lomvia*) and Black-legged Kittiwakes (*Rissa tridactyla*): at Cape Hay near the northwest tip and at Cape Graham Moore at the opposite end of the island. Although the size of these colonies has been estimated previously, there is no information on how the estimates were made, except for Thick-billed Murres at Cape Hay in 1977, when the numbers were based on sampling only about 30% of the colony. In 2013, high-resolution digital photographs of the whole area of both colonies were taken in July, when most birds were probably incubating eggs. Individual birds were counted on the photographs, and the numbers were corrected for image quality and converted to numbers of breeding pairs based on correction factors from another High Arctic colony. Our estimates were similar to those from earlier years for kittiwakes at Cape Graham Moore and for murres at Cape Hay, but suggested that numbers of murres were higher than previously thought at Cape Graham Moore, while numbers of kittiwakes were lower at Cape Hay. The overall total for the Canadian population of Thick-billed Murres was unaffected by these changes, but the total number of Black-legged Kittiwakes nesting in the Canadian Arctic may be 20% lower than previously thought.

Key Words: Population census; Bylot Island; Nunavut; Thick-billed Murre; *Uria lomvia*; Black-legged Kittiwake; *Rissa tridactyla*; Sirmilik National Park; Cape Graham Moore; Cape Hay

Introduction

The Lancaster Sound/Baffin Bay region is one of the richest marine areas in the Canadian Arctic (Nettleship 1974; McLaren and Renaud 1982; Finley *et al.* 1983; Wong *et al.* 2014). In summer, it supports large populations of marine mammals and birds, including most of the Canadian population of Narwhals (*Monodon monoceros*), large numbers of Belugas (*Delphinapterus leucas*) and Bowhead Whales (*Balaena mysticetus*; Laidre *et al.* 2015), and large colonies of marine birds, including Thick-billed Murres (*Uria lomvia*), Northern Fulmars (*Fulmarus glacialis*), and Black-legged Kittiwakes (*Rissa tridactyla*; Nettleship 1974; Brown *et al.* 1975; McLaren 1982). Despite the importance of this region for marine top predators, the size of populations, especially breeding populations of marine birds, is poorly known and many of the estimates available originate from surveys in the 1970s or earlier (Gaston *et al.* 2012).

The Thick-billed Murre is the most abundant seabird in the Canadian Arctic, breeding in ten large colonies from Akpatok Island, in Ungava Bay (60°15'N), north to Coburg Island (75°47'N), with an estimated total population of 1.5 million breeding pairs (Gaston *et al.* 2012). Knowledge of the total size of the population is important in managing the extensive hunt of these birds in their wintering area off Newfoundland and Labrador

(Elliot 1991; Chardine *et al.* 1999). In the Lancaster Sound/Baffin Bay region, an accurate estimate of population size is available for only one colony, at Prince Leopold Island at the western end of Lancaster Sound (Gaston and Nettleship 1981; Gaston *et al.* 2012).

Bylot Island, close to the north end of Baffin Island, is a Migratory Bird Sanctuary administered by Environment and Climate Change Canada and is also part of Sirmilik National Park. The island is the site of two major seabird colonies: one near Cape Graham Moore, at the southeast tip of the island (72°53'N, 76°10'W) and the other 8 km to the west of Cape Hay, near the northwestern tip (73°36'N, 80°19'W; Figure 1; Nettleship and Smith 1975). Both colonies are used by intermingled Thick-billed Murres and Black-legged Kittiwakes.

According to previous information, the colony at Cape Graham Moore was the smallest of the Canadian Thick-billed Murre colonies, estimated at 20 000 breeding pairs, based on an aerial survey in 1972 (Brown *et al.* 1975). However, the statement “Order 5” appeared in parentheses beside the number, indicating that it was a very approximate estimate. The larger colony near Cape Hay was estimated to contain 400 000 breeding pairs in 1957 (Tuck and Lemieux 1959), but an estimate by Birkhead and Nettleship (1980), based on counts of parts of the colony (about 30%) from photographs tak-

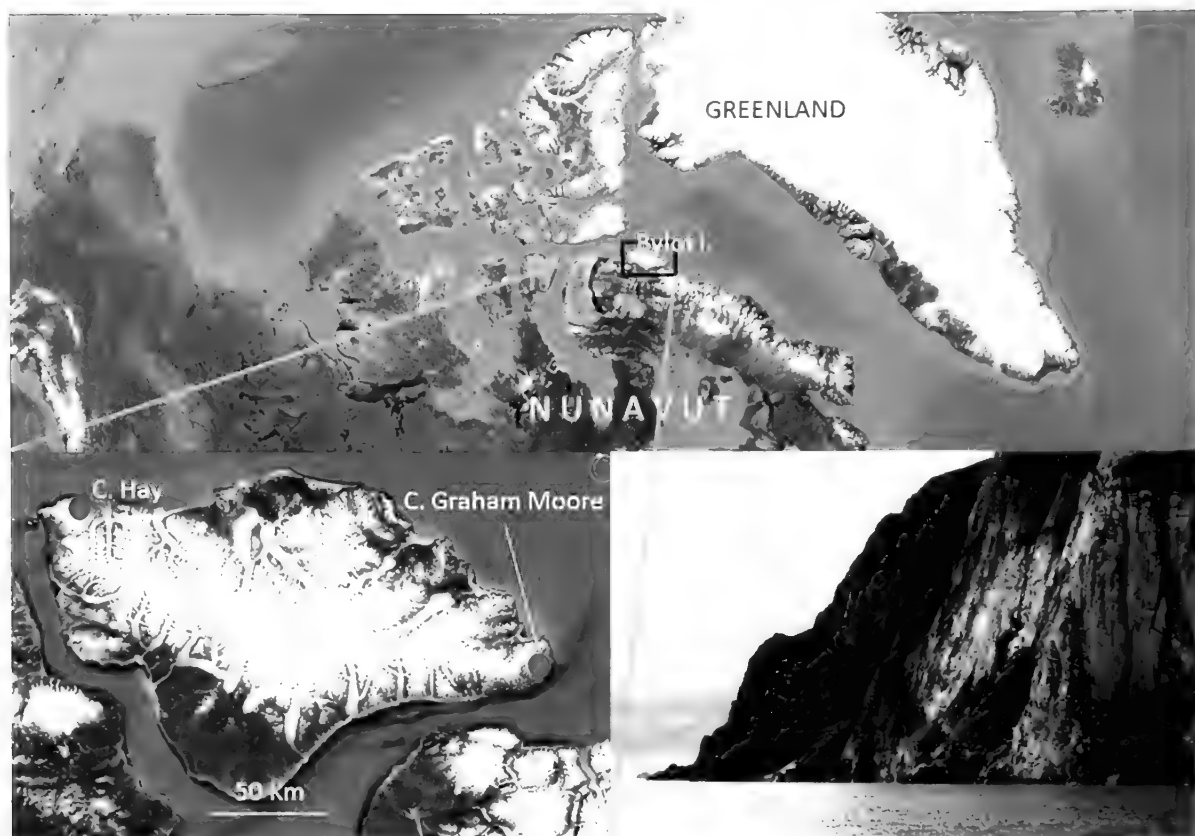


FIGURE 1. Google Earth image and inset show the location the Thick-billed Murre (*Uria lomvia*) and Black-legged Kittiwake (*Rissa tridactyla*) colonies studied: Cape Hay and Cape Graham Moore on Bylot Island (inset map: Google Earth V 7.1.5.1557 [13 December 2015]; accessed 30 April 2016). Inset photograph shows the Cape Graham Moore colony from the sea. Photo: K. O'Donovan.

en in 1976, suggested 140 000 pairs. More recent estimates were not available before the present study.

The cliffs of both colonies support smaller numbers of breeding Black-legged Kittiwakes. Tuck and Lemieux (1959) estimated 3000 pairs at Cape Graham Moore and 50 000 at Cape Hay in 1957, and Lepage *et al.* (1998) estimated 3000 and 20 000, respectively, based on surveys in the 1970s. However, there is no information on how any of these estimates were obtained.

No further attempts were made to census either of these colonies until 2013, when a set of high-resolution digital photographs was taken of both colonies. The objective was to count Thick-billed Murres and Black-legged Kittiwakes using a standardized procedure, so that subsequent counts can be readily compared with those obtained in 2013. We describe here the analysis of the photographs and provide a new census for the colonies: the first known to be based on complete counts of all the birds present.

Methods

Thick-billed Murres nest in large, dense colonies concentrated on the narrow ledges of steep cliffs. In most cases, part or all of the cliffs is invisible from land. Hence counts must be made from out at sea. However,

large colonies, such as those on Bylot Island, are extremely difficult to count from a ship, because of the movement of the vessel, which makes it difficult to keep track of what parts have already been counted. In addition, substantial time is required for the ship to reposition itself along the colony. The Cape Hay colony extends along 3.5 km of 300-m-high cliffs (area about 1 km², see Birkhead and Nettleship 1980), while that at Cape Graham Moore is 1 km long on 250-m cliffs (0.25 km²; Nettleship and Smith 1975).

It is customary elsewhere to take high-resolution photographs of these colonies and to count the birds on the resulting images (e.g., Birkhead and Nettleship 1980; Gaston 2002). Photographic surveys were made on 17 July 2013 at Cape Graham Moore and on 22 and 24 July 2013 at Cape Hay. On 22 July, the colony was partly obscured by fog, making bird counts from the photographs difficult. Consequently, we used only those taken on 24 July. Because of the size of the colonies and the need for photos to be taken as perpendicular to the cliffs as possible, the ship had to be repositioned frequently; thus, photography took most of the day. Photographs counted covered the entire length of occupied cliffs at Cape Graham Moore and Cape Hay with up to 50% overlap between adjacent photos.

At both locations, photographs were obtained using a Canon 5D Mark 3 camera and Canon EF 70–200 mm f2.8L IS II USM lens (Canon Inc., Brampton, Ontario, Canada) by a photographer (K.O.) stationed about 2 m above the sea and roughly 200 m from the cliffs on board the MV *Arctic Tern*. Original images were in cr2 format, the output format from Canon cameras. They were converted to jpeg images for processing using Irfanview free software for batch image conversion (version 4.38; Irfan Skiljan, Wiener Neustadt, Austria; www.irfanview.com).

On the photographs, Thick-billed Murres were distinguished from other birds that might have been present by the sharp distinction between their white front and black backs and their robust shape. The white tips of their secondary feathers, contrasting with the charcoal primary feathers, were also a useful identification feature in poor lighting conditions. Black-legged Kittiwakes were identified by their strikingly white heads, shared at these colonies only by small numbers of the much larger Glaucous Gull (*Larus hyperboreus*). Only birds perched on the cliffs were counted; those in flight or on the sea were ignored.

Counts of birds were made using GIMP photo-editing software (version 2.6.11; The GIMP Team, www.gimp.org/). Before counting, all photos were inspected and compared to identify the clearest images for each section of the colony. In GIMP, transparent layers were created and superimposed over the colony photos. Portions of a photo that were already counted were delimited in a layer named “Boundary.”

Birds were counted by placing a dot of known pixel number on each bird in a layer named “Count” using the Pencil tool with brush setting at Circle (11) and scale at 0.27, giving a square dot of 9 pixels (3 pixels by 3 pixels). The number of pixels in a layer was counted automatically in the Histogram tool with channel set to “Value”. Histogram pixel counts were verified for the first birds counted and regularly during the count to ensure that drawing settings were not accidentally modified. When a dot had been placed on every bird, the histogram pixel count was recorded and divided by the dot size (9 pixels) to obtain the number of birds.

Photo quality was recorded on a scale of 1 (best) to 3 (worst; Figure 2). Quality 1 photos had good lighting conditions, and individual Thick-billed Murres could be readily distinguished. Quality 3 photos had poor lighting, fog, or low picture resolution because of distance, so that some individuals could not be accurately distinguished or were obscured on dark areas of the cliff. To obtain an idea of the bias created by image quality, we counted some images very carefully to assess where birds might have been missed, but found only a small number of “possible birds”, which could not be identified with certainty; the exact number could not be determined, but these amounted to fewer than 5% of those counted. Hence, to correct for image quality, we assumed, arbitrarily, that all birds present could be counted on quality 1 images, 97% on quality 2 images, and 95% on quality 3 images.

Corrected counts of Thick-billed Murres were converted to numbers of breeding pairs using a conversion factor k , where k is the number of known breeding pairs divided by number of birds counted and is derived from breeding study plots on the colony at Prince Leopold Island (Gaston and Nettleship 1981). The Prince Leopold Island counts were made at a similar date (8–26 July) to those conducted here, which was mid-late incubation period at that colony. Although we do not know the timing of breeding at Bylot Island in 2013, it is likely that birds counted in this study would also have been in the middle of incubation (Gaston and Hipfner 2000). The mean value of k for Prince Leopold Island in 1976 and 1977 was 0.73 (standard deviation [SD] 0.07; Appendix 8 of Gaston and Nettleship 1981).

Data on the conversion of counts of individual Black-legged Kittiwakes to breeding pairs is less extensive than for Thick-billed Murres. We used the ratio during incubation of known breeding pairs (sites where at least one egg was laid) to individuals, counted at one study plot containing 75 active nests on Prince Leopold Island in 2012, where the ratio was 0.56 (A.J.G., unpublished data).

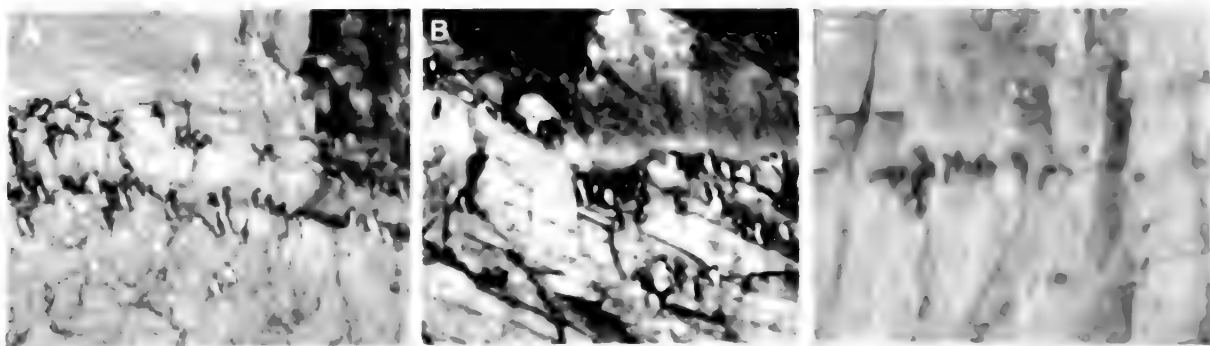


FIGURE 2. Sample photos of Thick-billed Murre (*Uria lomvia*) colonies with assigned quality of, left to right, 1, 2, and 3. Photos: K. O'Donovan.

Results

The Cape Graham Moore count resulted in 69 255 Thick-billed Murres (time taken to count the images 22 h 44 m). Picture quality was variable, with most birds counted on quality 2 images (Table 1). The estimate after correcting for quality was 71 568 birds which, after *k* correction, suggests 51 887 breeding pairs (SD 4723; 95% range 42 440–61 334). We counted 4568 Black-legged Kittiwakes on the same photographs, of which all but 1% were on images of quality 1 or 2. After correction for image quality, this becomes 2620 breeding pairs (Table 1).

The Cape Hay count for 24 July 2013 resulted in 110 813 Thick-billed Murres (counting time 29 h 2 m) with most counted on quality 2 images. This converts to an estimate of 83 012 breeding pairs (SD 7557; 95% range 67 898–98 126; Table 1). Corresponding numbers for Black-legged Kittiwakes were 20 682 counted representing 11 922 breeding pairs (counting time 6 h 4 m).

Discussion

Single “snapshot” counts of seabird colonies will not normally give an accurate estimate of the number of breeding pairs because the number of birds present varies with weather, time of day, and season (Gaston and Nettleship 1981; Gaston 2002). In all cases, our counts were likely to have been underestimates, because in high concentrations of murres, it may be difficult to distinguish individuals on low-quality photos. This effect was probably more pronounced where photo quality was low or near the top of cliffs where the angle between the direction of the camera and the horizontal was greatest. Because Black-legged Kittiwakes nest exclusively on vertical portions of cliffs and because their white heads are prominent, we think that few are likely to have been missed, except where one bird was sitting behind another.

Given that our photos were taken in good weather and at various times of day, at the same stage of the

breeding season as when the correction factors were derived, weather and seasonal bias should be relatively small. The main source of inaccuracy was probably the conversion ratios from individuals counted to breeding pairs. Variance in the value of *k* for Prince Leopold Island may not be representative of that for Cape Hay; even if they were similar under similar conditions, 2013 may have been an unusual year in ways that we cannot measure. Nevertheless, our estimates should represent a closer approximation of the true size of these colonies than previous estimates at the time they were made. Our value of *k* = 0.73 falls in the middle of the range of published values for Thick-billed Murre colonies from Alaska to eastern Nunavut (Chapdelaine *et al.* 1986; Hatch and Hatch 1989; Gaston *et al.* 1993).

Black-legged Kittiwakes elsewhere are often counted as “apparently occupied nests”, based on a bird in attendance or a nest that looks as though it had been constructed or reconstructed in the year of the count (Mitchell *et al.* 2004; Mallory *et al.* 2009). We chose not to adopt this technique because, given the greyish colour of the rock and the nests, on most of the images it was much easier to identify birds than nests. This can be seen in Figure 2C, where five kittiwakes can be discerned, but no nests are visible, although several of the birds would almost certainly have been standing on nests.

With a minimum estimate of more than 40 000 pairs of murres at Cape Graham Moore, our results suggest that the size of this colony is more than double previous estimates. On the other hand, the maximum estimate for Cape Hay, at less than 100 000 pairs, is 29% below the previous estimate (140 000 pairs; Birkhead and Nettleship 1980). However, given that the earlier estimate was based on a count of only about 30% of the colony, the current estimate cannot be taken as evidence of a population reduction since 1976, when the previous photos were taken. Pending better information from locally derived *k* values or better photographs, we suggest that the size of the Cape Hay murre colony be

TABLE 1. Counts of Thick-billed Murres (*Uria lomvia*) and Black-legged Kittiwakes (*Rissa tridactyla*) at the Cape Graham Moore and Cape Hay colonies, Bylot Island in 2013, and estimated numbers of breeding pairs.

Colony	Photo quality	Thick-billed Murre			Black-legged Kittiwake		
		% photos of this quality	Bird count	Corrected count	% photos of this quality	Bird count	Corrected count
Cape Graham Moore	1	6	3 928	3 928	22	1 011	1 011
	2	75	51 846	53 449	77	3 536	3 645
	3	19	13 481	14 191	1	21	22
Total			69 255	71 568		4 568	4 678
Pair equivalent			50 210	51 887		2 558	2 620
Standard deviation			4 571	4 723			
Cape Hay	1	10	11 160	11 160	17	3 499	3 499
	2	65	71 793	74 013	66	13 652	14 074
	3	25	27 860	29 326	17	3 531	3 717
Total			110 813	114 500		20 682	21 290
Pair equivalent			80 339	83 012		11 582	11 922
Standard deviation			7 314	7 557			

treated as 70 000–100 000 breeding pairs (rounded to the nearest 10 000) and the Cape Graham Moore colony as 40 000–60 000 breeding pairs. The aggregate count for the two colonies is similar to previous estimates of their combined population (160 000 pairs; Brown *et al.* 1975). Hence our estimates do not adjust the estimate of the total population of Canada's eastern Arctic.

It is impossible to say with certainty that there was a decrease at Cape Hay between Tuck and Lemieux's (1959) estimate of 400 000 pairs in 1957 and the estimate of 140 000 pairs presented by Birkhead and Nettleship (1980) based on photos taken in 1976, as we have no indication of Tuck and Lemieux's earlier methods. Lepage *et al.* (1998) and Gaston and Robertson (2014) suggested that the murre population of Cape Hay may have declined during the 1960s because of incidental drowning of birds in the west Greenland salmon drift-net fishery and excessive hunting during fall and winter in west Greenland and Newfoundland–Labrador (Tull *et al.* 1972; Nettleship and Evans 1985). Monitoring in 1989 suggested that both murre colonies on Bylot Island were “relatively stable” (Lepage *et al.* 1998), but, again, details are unknown. However, it seems from our result that the size of the colony at Cape Hay has changed little since 1975.

We have no way to estimate variance for our kittiwake counts, but, if they are similar to those of the murres, we can expect that the true breeding population of the Cape Graham Moore colony is 2000–3000 pairs and the Cape Hay colony 10 000–15 000 pairs. The Cape Graham Moore estimate is similar to Tuck and Lemieux's (1959) 1957 estimate (3000 pairs), but the estimate for Cape Hay is substantially lower than earlier estimates. In the absence of more details on the earlier counts, it is impossible to know whether this represents a decrease in numbers since the 1970s. However, it adjusts the total estimate for Black-legged Kittiwakes in Canada's eastern Arctic downward by about 20%, from 123 000 (Gaston *et al.* 2012) to about 100 000 breeding pairs.

The difference between our estimates and earlier ones suggests that similar intensive counts would be useful for many other large Arctic seabird colonies where population numbers are currently based on undocumented and, in many cases, decades-old estimates.

Acknowledgements

For assistance with this project, we thank the captain and crew of MV *Arctic Tern* and Garry Donaldson and Cynthia Pekarik of Environment and Climate Change Canada.

Literature Cited

- Birkhead, T. R., and D. N. Nettleship. 1980. Census methods for murres, *Uria* species: a unified approach. Occasional paper 43. Canadian Wildlife Service, Ottawa, Ontario, Canada.

- Brown, R. G. B., D. N. Nettleship, P. Germain, C. E. Tull, and T. Davis. 1975. Atlas of Eastern Canadian Seabirds. Canadian Wildlife Service, Ottawa, Ontario, Canada.
- Chapdelaine, G., A. J. Gaston, and P. Brousseau. 1986. Censusing the Thick-billed Murre colonies of Akpatok Island. Progress note 163. Canadian Wildlife Service, Ottawa, Ontario, Canada.
- Chardine, J., B. Collins, R. D. Elliot, H. Lévesque, and P. Ryan. 1999. Trends in annual harvest of murres in Newfoundland and Labrador. *Bird Trends* 7: 11–14.
- Elliot, R. D. 1991. The management of the Newfoundland turr hunt. Pages 29–35 in *Studies of High Latitude Seabirds*. 2. Conservation Biology of the Thick-billed Murre in the Northwest Atlantic. Edited by A. J. Gaston and R. D. Elliot. Occasional paper 69. Canadian Wildlife Service, Ottawa, Ontario, Canada.
- Finley, K. J., G. W. Miller, R. A. Davis, and W. R. Kosk. 1983. A distinctive large breeding population of Ringed Seals (*Phoca hispida*) inhabiting the Baffin Bay pack ice. *Arctic* 36: 162–173. <https://doi.org/10.14430/arctic2259>
- Gaston, A. J. 2002. Results of monitoring Thick-billed Murre populations in the eastern Canadian Arctic, 1976–2000. Occasional paper 106. Canadian Wildlife Service, Ottawa, Ontario, Canada.
- Gaston, A. J., and J. M. Hipfner. 2000. Thick-billed Murre (*Uria lomvia*). In *The Birds of North America*. Edited by P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. Accessed 15 March 2016. <https://birdsna.org/Species-Account/bna/species/thbmur>.
- Gaston, A. J., and D. N. Nettleship. 1981. The Thick-billed Murres of Prince Leopold Island. Monograph 6. Canadian Wildlife Service, Ottawa, Ontario, Canada.
- Gaston, A. J., and G. J. Robertson. 2014. A review of Thick-billed Murre banding in the Canadian Arctic, 1950–2010. *Arctic* 67: 441–448. <https://doi.org/10.14430/arctic4419>
- Gaston, A. J., L. N. de Forest, H. G. Gilchrist, and D. N. Nettleship. 1993. Monitoring Thick-billed murre populations at colonies in northern Hudson Bay, 1972–1992. Occasional paper 80. Canadian Wildlife Service, Ottawa, Ontario, Canada.
- Gaston, A. J., M. L. Mallory, and H. G. Gilchrist. 2012. Populations and trends of Canadian Arctic seabirds. *Polar Biology* 35: 1221–1232. <https://doi.org/10.1007/s00300-012-1168-5>
- Hatch, S. A., and M. A. Hatch. 1989. Attendance patterns of murres at breeding sites: implications for monitoring. *Journal of Wildlife Management* 53: 483–493. <https://doi.org/10.2307/3801154>
- Laidre, K. L., H. Stern, K. M. Kovacs, L. Lowry, S. E. Moore, E. V. Regehr, S. H. Ferguson, O. Wiig, P. Boveng, R. P. Angliss, E. W. Born, D. Litovka, L. Quakenbush, C. Lydersen, D. Vongraven, and F. Ugarte. 2015. Arctic marine mammal population status, sea ice habitat loss, and conservation recommendations for the 21st century. *Conservation Biology* 29: 1523–1739. <https://doi.org/10.1111/cobi.12474>
- Lepage, D., D. N. Nettleship, and A. Reed. 1998. Birds of Bylot Island and adjacent Baffin Island, Northwest Territories, Canada, 1979 to 1997. *Arctic* 51: 125–141. <https://doi.org/10.14430/arctic1054>
- Mallory, M. L., J. Akecarok, and A. J. Gaston. 2009. Status of black-legged kittiwake (*Rissa tridactyla*) colonies in the Canadian High Arctic. *Arctic* 62: 96–101. <https://doi.org/10.14430/arctic116>

- McLaren, P. L.** 1982. Spring migration and habitat use by seabirds in eastern Lancaster Sound and western Baffin Bay. *Arctic* 35: 88–111. <https://doi.org/10.14430/arctic2310>
- McLaren, P. L., and W. E. Renaud.** 1982. Seabird concentrations in late summer along the coasts of Devon and Ellesmere Islands, N.W.T. *Arctic* 35: 112–117. <https://doi.org/10.14430/arctic2311>
- Mitchell, P. I., S. F. Newton, N. Ratcliffe, and T. E. Dunn.** 2004. Seabird Populations of Britain and Ireland. T. and A. D. Poyser, London, United Kingdom.
- Nettleship, D. N.** 1974. Seabird colonies and distributions around Devon Island and vicinity. *Arctic* 27: 95–103. <https://doi.org/10.14430/arctic2860>
- Nettleship, D. N., and P. G. H. Evans.** 1985. Distribution and status of the Atlantic Alcidae. Pages 53–154 in *The Atlantic Alcidae: The Evolution, Distribution and Biology of the Auks Inhabiting the Atlantic Ocean and Adjacent Water Areas*. Edited by D. N. Nettleship and T. R. Birkhead. Academic Press, London, United Kingdom.
- Nettleship, D. N., and P. A. Smith.** 1975. Ecological Sites in Northern Canada. Canadian Committee for the International Biological Programme, Ottawa, Ontario, Canada.
- Tuck, L. M., and L. Lemieux.** 1959. The avifauna of Bylot Island. *Dansk Ornithologisk Forening Tidsskrift* 53: 137–154.
- Tull, C. E., P. Germain, and A. W. May.** 1972. Mortality of thick-billed murres in the West Greenland salmon fishery. *Nature (London)* 237: 42–44. <https://doi.org/10.1038/237042a0>
- Wong, S. N. P., C. Gjerdrum, K. H. Morgan, and M. L. Mallory.** 2014. Hotspots in cold seas: the composition, distribution, and abundance of marine birds in the North American Arctic. *Journal of Geophysical Research: Oceans*. 119: 1691–1705. <https://doi.org/10.1002/2013JC009198>

Received 2 June 2016

Accepted 15 March 2017

Thematic Collection

Thematic Collection: Alvars in Canada

DANIEL F. BRUNTON^{1,3} and PAUL M. CATLING²

¹216 Lincoln Heights Road, Ottawa, Ontario K2B 8A8 Canada

²170 Sandford Avenue, Ottawa, Ontario K2C 0F9 Canada

³Corresponding author: danielbrunton2@gmail.com

Brunton, Daniel F., and Paul M. Catling. 2017. Thematic Collection: alvars in Canada. *Canadian Field-Naturalist* 131(1): 75–79
<https://doi.org/10.22621/cfn.v131n1.1962>

This is the first Thematic Collection of *The Canadian Field-Naturalist*, an initiative of the Ottawa Field-Naturalists' Club (OFNC) Publications Committee. Thematic Collections are editor-selected compilations of previously published contributions to both *The Canadian Field-Naturalist* (CFN) and to the OFNC's regional publication, *Trail & Landscape* (T&L), on a central theme with links to each article. The articles concern alvar landscapes, species that occur on alvars, and the conservation of alvar habitats. We estimate that the titles assembled here from those two publications represent 50% of the important papers published on Canadian alvars.

Alvars are very unusual natural habitats that to some extent are relicts of early postglacial times. They contain rare, restricted, endemic, and endangered species in most groups of organisms, are important for human recreation, and also contain important native crop germplasm. Biodiversity is high and up to 400 native plant species may occur on particular alvar landscapes. Up to 150 species of plants can occur on a 2 ha site.

Traditionally alvars have been defined as more or less naturally treeless (open) areas on thin soil over essentially flat limestone or marble rock (Figures 1–3). Ever-changing alvar plant communities are a consequence of some combination (depending on geography) of annual and/or periodic drought, fire, flooding, grazing, extreme temperatures, scouring, and ice uplift. They occur within generally forested, cool temperate regions. Although the term was initially confined to open rock pavement and meadow areas in Canada, it has most recently been applied to some semi-forested landscapes, including both “open alvar” and “alvar woodland”. A final aspect of the definition includes the idea that alvars are self-sustaining but dynamic – what is open alvar today may be alvar woodland 200 years from now, and *vice versa*.

The “limestone barrens” of northwestern Newfoundland could be called alvars, but they have always been given the former name by local people. The Cedar Glades of the eastern US are strictly open areas and are older landscapes that also typically are drier, hotter, and



FIGURE 1. Alvar opening on the Carden Plain, City of Kawartha, Ontario (9 June 2009). The pink colour in the lower part of this photo is Prairie Smoke (*Geum triflorum* Pursh). Photo: D. F. Brunton.

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalists' Club.



FIGURE 2. Alvar pavement, Great LaCloche Island, Manitoulin, Ontario (8 August 2011). Photo: D. F. Brunton.



FIGURE 3. Alvar meadow with yellow Balsam Ragwort (*Packera paupercula* (L.) A. & D. Love) and red Indian Paintbrush (*Castilleja coccinea* (L.) Spreng.) on the Carden Plain, City of Kawartha, Ontario (9 June 2009). Photo: D. F. Brunton.

experience less harsh winter conditions. In the Midwest, limestone prairies are similar to alvars in some respects but usually have a distinctive prairie composition. The term alvar has been used extensively in the sense of the preceding paragraph in the Great Lakes region of North America, the Baltic region of Northern Europe, and western Ireland. In Canada, alvars occur in

northwestern Newfoundland, southwestern Quebec, southern Ontario, the Interlake region of Manitoba, and on the southwest side of Great Slave Lake in Northwest Territories (Figure 4).

The study and understanding of Canadian alvars began about 50 years ago. An Austrian-born and European trained scientist (mostly an arctic lichenologist),

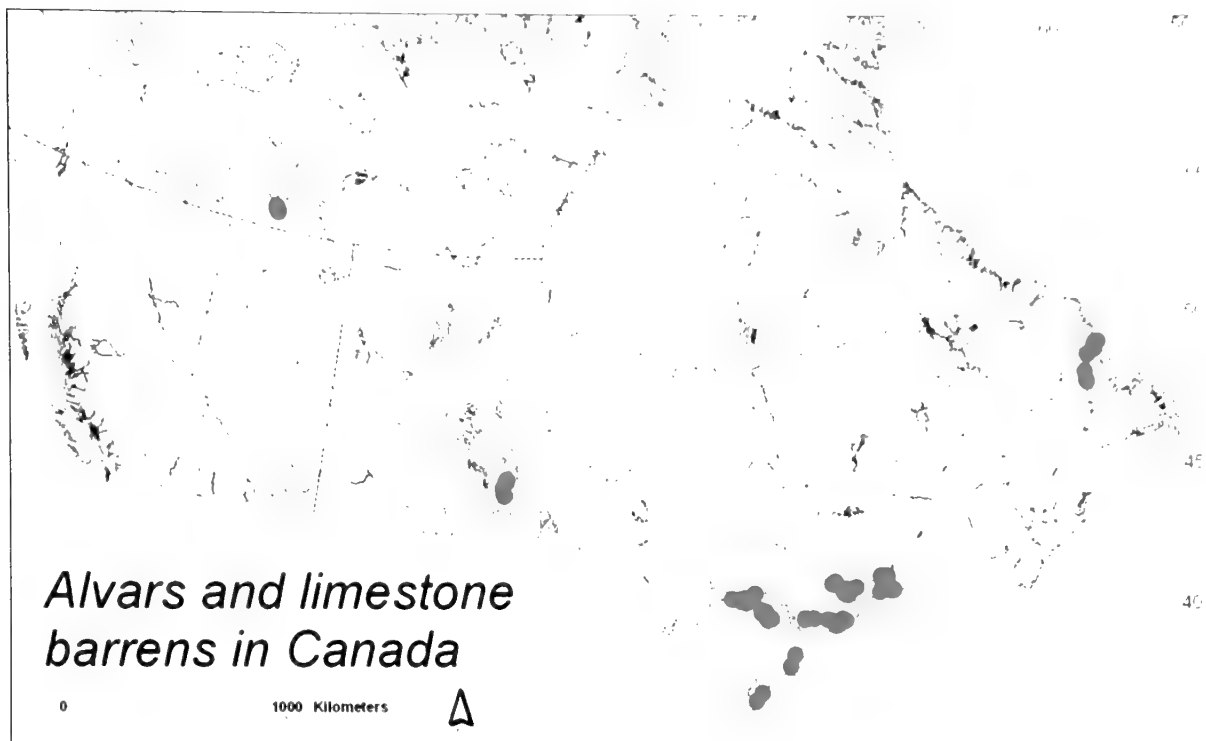


FIGURE 4. Distribution of alvar landscapes in Canada (reproduced with permission from Catling *et al.* 2014).

Roland Beschel was working at Queens University in Kingston in the 1960s. With experience in northern Europe he realized that there were alvars around Kingston. Beschel died suddenly in 1971, before being able to initiate any detailed studies. However, he did tell his students about the local alvars and he also wrote a few very general articles about the Ontario alvars. Beschel's information became the basis for further study; the first comprehensive review article about Ontario alvars was published in 1975 in the *Ontario Field Biologist*. Soon after that and until 1994 as the exceptional natural features of alvars became better known, many researchers and natural resource agencies completed life science inventories of alvars in Ontario. It became apparent that alvars existed throughout the Great Lakes region and that a universal approach to the description of alvar types and their communities was needed.

An international alvar initiative was established in 1994 to provide both a profile and a universal approach. It brought experts from all Great Lakes jurisdictions together to prepare an inventory report with recommendations. This had substantial impact. As a result of the initiative, many people became interested in alvar research and several important theses and other work resulted. As well as increasing awareness, the initiative led to increased protection of alvar habitat in Ontario, New York, and Michigan. One of the best examples of this was in Ontario. In 2003, the Ontario government established the 516 ha Burnt Lands Provincial Park in the City of Ottawa specifically to protect alvar habitat. Over the past decade and a half, the Nature Conservancy of Canada, cooperating with the Couchiching Conservancy and the Ontario Ministry of Natural Resource-

es and Forestry, purchased a number of large alvar properties in Carden Township, City of Kawartha. In 2014 Ontario Parks amalgamated a number of these to form the core of Carden Alvar Provincial Park encompassing 1917 ha. This was a major step because of the size of this alvar landscape, but many smaller and some richer sites have also been protected in Ontario within provincial parks, conservation reserves, and through municipal zoning. Educational programs, agreements, and easements have been applied to many other alvar properties.

Another improvement over the past few decades has been our understanding of appropriate management of alvar landscapes. A good example is the Stone Road Alvar on Pelee Island and perhaps the nearby (also on Pelee Island) Brown's Road Alvar, and savannah sites (Red Cedar, Verbeek). Here succession of more open alvar conditions to thickets and cool season grasses is causing a decline in alvar species. Fire and mechanical thinning are being used to reduce the thickets, but some are left for birds including provincially significant Yellow Breasted Chat (*Icteria virens* L.) and care is taken not to disturb rare snakes. Restricted plants, including Whorled Milkweed (*Asclepias verticillata* L.), Blue Ash (*Fraxinus quadrangulata* Michx.), Nodding Onion (*Allium cernuum* Roth), Grey-headed Coneflower (*Ratibida pinnata* (Vent.) Barnh.), Downy Woodmint (*Blephilia ciliata* (L.) Benth.), Oval Ladies Tresses (*Spiranthes ovalis* Lindl.), and Narrow-leaved Paleseed (*Leucospora multifida* (Michaux) Nuttall), have been successfully promoted.

As a result of being very unusual habitats and containing rare, endangered, and endemic species, alvars

are of great interest to science, but unusual flora and fauna has also become a very popular recreation target. Thousands of people visit the Carden Alvar IBA (Important Bird Area) every year. Many come to see the endangered or threatened wildlife such as Loggerhead Shrikes (*Lanius ludovicianus* L.), Bobolink (*Dolichonyx oryzivorus* L.), or Blanding's Turtles (*Emys blandingii* Holbrook), but others just come to enjoy the open landscape with their astonishing carpets of wildflowers.

Alvars and alvar complexes vary within different geographic regions (Figure 4). Although many large Ontario alvar landscapes have been protected over the past few decades (e.g., Manitoulin Island, Bruce Peninsula, Carden Plain) as well as alvars in the Interlakes Region of Manitoba and the limestone barren alvars of northern Newfoundland, there are still some major gaps in the system of representative protected sites. These include globally significant alvar habitat on the Napanee Plain in Ontario and alvar remnants in western Quebec. Many groups of organisms on alvars and some alvar habitats remain poorly known. The fact that alvars are relicts makes them ideal for research aimed at a better understanding of ecology and evolution.

Collection of Papers

- Brunton, D. F.** 1988. The Clay Bank Alvar. *Trail & Landscape* 22: 53–65. Accessed 15 June 2017. <http://www.biodiversitylibrary.org/item/202202#page/23/mode/1up>.
- Brunton, D. F.** 2015. Great Plains Ladies'-tresses (*Spiranthes magnicamporum*) in the lower Great Lakes region and a new record for New York State. *Canadian Field-Naturalist* 129: 183–188. <https://doi.org/10.22621/cfn.v129i2.1700>
- Catling, P. K.** 2013. Status of Jelly Strap Lichen, *Thyrea confusa*, in the area of Burnt Lands Provincial Park. *Trail & Landscape* 47: 124–128. <https://doi.org/10.6084/m9.figshare.5109958.v1>
- Catling, P. M.** 1995. The extent of confinement of vascular plants to alvars in southern Ontario. *Canadian Field-Naturalist* 109: 172–181. Accessed 19 June 2017. <http://biodiversitylibrary.org/page/35457020>.
- Catling, P. M.** 2009. Vascular plant diversity in burned and unburned alvar woodland: more evidence of the importance of disturbance to biodiversity and conservation. *Canadian Field-Naturalist* 123: 240–245. <https://doi.org/10.22621/cfn.v123i3.971>
- Catling, P. M.** 2013a. Can we create alvars or fully restore those damaged? *Canadian Field-Naturalist* 127: 97–101. <https://doi.org/10.22621/cfn.v127i1.1428>
- Catling, P. M.** 2013b. Ecological and geographical separation of three varieties of *Sporobolus vaginiflorus* (Poaceae) in eastern Ontario. *Canadian Field-Naturalist* 127: 155–163. <https://doi.org/10.22621/cfn.v127i2.1446>
- Catling, P. M.** 2014. Impact of the 2014 drought on woody vegetation invading alvar grasslands in the Burnt Lands Alvar, eastern Ontario. *Canadian Field-Naturalist* 128: 243–249. <https://doi.org/10.22621/cfn.v128i3.1602>
- Catling, P. M.** 2015. *Osmia* species (Megachilidae) pollinate *Cypripedium parviflorum* (Orchidaceae) and *Packeria paupercula* (Asteraceae): a localized case of Batesian mimicry. *Canadian Field-Naturalist* 129: 38–44. <https://doi.org/10.22621/cfn.v129i1.1665>
- Catling, P. M., and V. R. Brownell.** 1995. A review of the alvars of the Great Lakes region: distribution, floristic composition, phytogeography and protection. *Canadian Field-Naturalist* 109: 143–171. <http://biodiversitylibrary.org/page/35456991>.
- Catling, P. M., and V. R. Brownell.** 1998. Importance of fire in the maintenance of distinctive, high biodiversity plant communities on alvar – evidence from the Burnt Lands, eastern Ontario. *Canadian Field-Naturalist* 112: 661–667. Accessed 19 June 2017. <http://biodiversitylibrary.org/page/34258017>.
- Catling, P. M., and V. R. Brownell.** 1999a. Additional notes on the vegetation of dry openings along the Trent River, Ontario. *Canadian Field-Naturalist* 113: 506–509. Accessed 19 June 2017. <http://biodiversitylibrary.org/page/34235372>.
- Catling, P. M., and V. R. Brownell.** 1999b. An objective classification of Ontario Plateau alvars in the northern portion of the Mixedwood Plains Ecozone and a consideration of protection frameworks. *Canadian Field-Naturalist* 113: 569–575. Accessed 19 June 2017. <http://biodiversitylibrary.org/page/34235439>.
- Catling, P. M., and V. R. Catling.** 1993. Floristic composition, phytogeography and relationships of prairies, savannas and sand barrens along the Trent River, eastern Ontario. *Canadian Field-Naturalist* 107: 24–45. Accessed 19 June 2017. <http://biodiversitylibrary.org/page/34810162>.
- Catling, P. M., and R. A. Layberry.** 2013. An alvar race of the *couperi* subspecies of the Silvery Blue (*Glaucopsyche lygdamus couperi*) in southeastern Ontario. *Canadian Field-Naturalist* 127: 224–228. <https://doi.org/10.22621/cfn.v127i3.1487>
- Catling, P. M., S. M. McKay, B. Kostiuk, and A. Kuja.** 2012. Ostrander Point – will it still be a hotspot? *Trail & Landscape* 46: 117–132. <https://doi.org/10.6084/m9.figshare.5109934>
- Catling, P. M., and A. Sinclair.** 2002. Initial beneficial effects of fire and bulldozing on Neglected Milkvetch, *Astragalus neglectus*, in an eastern Ontario Alvar Woodland. *Canadian Field-Naturalist* 116: 640–642. Accessed 19 June 2017. <http://biodiversitylibrary.org/page/35151886>.
- Catling, P. M., A. Sinclair, and D. Cuddy.** 2001. Vascular plants of a successional alvar burn 100 days after a severe fire and their mechanisms of re-establishment. *Canadian Field-Naturalist* 115: 214–222. Accessed 19 June 2017. <http://biodiversitylibrary.org/page/34995288>.
- Catling, P. M., A. Sinclair, and D. Cuddy.** 2002. Plant community composition and relationships of disturbed and undisturbed alvar woodland. *Canadian Field-Naturalist* 116: 571–579. <http://biodiversitylibrary.org/page/35151817>.
- Dugal, A., and J. Reddoch.** 1980. Morris Island. *Trail & Landscape* 14: 18–23. https://figshare.com/articles/Dugal_A_Reddoch_J_1980_Morris_Island_Trail_Landscape_14_18-23/_5135710.
- Friesen, C., and C. Murray.** 2015. Gastony's Cliffbrake (*Pellaea gastonyi*) in Manitoba: new records and assessment of conservation status. *Canadian Field-Naturalist* 129: 45–52. <https://doi.org/10.22621/cfn.v129i1.1666>
- Hainault, R.** 1966. Some features of the flora of the Islands of Eastern Lake Ontario. *Canadian Field-Naturalist* 80: 69–73. Accessed 19 June 2017. <http://biodiversitylibrary.org/page/28034087>.
- Hanrahan, C.** 2016. Conservation Award – Non-member: Miller Paving Company [Braeside Alvar]. *Canadian Field-Naturalist* 130: 186. <https://doi.org/10.22621/cfn.v130i2.1855>

- Huggett, I.** 1993. The discovery of alvars at Aylmer. *Trail & Landscape* 27: 55–57. <https://doi.org/10.6084/m9.figshare.5109994>
- Kostiuk, B.** 2010. Rainy day discoveries in the Burnt Lands. *Trail & Landscape* 44: 40–42. <https://doi.org/10.6084/m9.figshare.5109937>
- Layberry, R. A., and P. M. Catling.** 2016. Cream Pincushions (*Scabiosa ochroleuca*; Dipsacaceae), a new established exotic plant in eastern Canada. *Canadian Field-Naturalist* 130: 137–139. <https://doi.org/10.22621/cfn.v130i2.1836>
- Neufeld, R., C. Hamel, and C. Friesen.** *In review*. Manitoba's endangered alvars: an initial description of their extent and status. *Canadian Field-Naturalist*.
- Reddoch, J.** 1979. Butterflies in the Innis Point Area. *Trail & Landscape* 13: 177. <https://doi.org/10.6084/m9.figshare.5110039>
- Reddoch, J. M., P. M. Catling, and A. H. Reddoch.** 2013. Great Plains Ladies'-tresses, *Spiranthes magnicamporum*: disjunct in eastern Ontario and a new orchid species for the Ottawa district and Lanark County. *Canadian Field-Naturalist* 127: 348–351. <https://doi.org/10.22621/cfn.v127i4.1518>
- Senn, H. A.** 1941. Notes on rare Canadian plants. II. [*Polycnemum arvensis* L.]. *Canadian Field-Naturalist* 55: 17–19. Accessed 19 June 2017. <http://biodiversitylibrary.org/page/28033831>.
- Taylor, A. N., and P. M. Catling.** 2011. Bees and butterflies in burned and unburned alvar woodland: evidence for the importance of postfire succession to insect pollinator diversity in an imperiled ecosystem. *Canadian Field-Naturalist* 125: 297–306. <https://doi.org/10.22621/cfn.v125i4.1258>
- White, D. J.** 1979a. Burnt Lands alvar. *Trail & Landscape* 13: 34–38. <https://doi.org/10.6084/m9.figshare.5110009>
- White, D. J.** 1979b. The flora of Innis Point. *Trail & Landscape* 13: 174–177. Erratum: 1980. 14: 28. <https://doi.org/10.6084/m9.figshare.5110018>
- Additional References**
- Belcher, J. W., P. A. Keddy, and P. M. Catling.** 1992. Alvar vegetation in Canada: a multivariate description at two scales. *Canadian Journal of Botany* 70: 1279–1291. <https://doi.org/10.1139/b92-161>
- Beschel, R. E.** 1965. Comments on the vegetation of the Kingston region. *Blue Bill* 12: 32–36.
- Beschel, R. E.** 1967. Field trip no. 1 to the Kingston region. *Canadian Botanical Association Annual Meeting*.
- Beschel, R. E.** 1968. Taimestiku uurimine kagu-ontarios. *Eesti Loodus [Estonian Nature]* 11: 423–425.
- Beschel, R. E.** 1969. Plant communities in the Kingston region. Symposium on geobotany of southern Ontario. Royal Ontario Museum, Toronto, Ontario, Canada.
- Bouchard, P., T. A. Wheeler, and H. Goulet.** 2005. Ground beetles (Coleoptera: Carabidae) from alvar habitats in Ontario. *Journal of the Entomological Society of Ontario* 136: 3–23. Accessed 19 June 2017. http://www.entsocnt.ca/uploads/3/0/2/6/30266933/136_3_23.pdf.
- Brownell, V. R., and J. L. Riley.** 2000. The Alvars of Ontario: Significant Alvar Natural Areas in the Ontario Great Lakes Region. Federation of Ontario Naturalists, Toronto, Ontario, Canada.
- Catling, P. M.** 2009. Composition, phylogeography, and relict status of the vascular flora of alvars and cliff tops southwest of Great Slave Lake, Northwest Territories, Canada. *Rhodora* 111(946): 189–208. <https://doi.org/10.3119/08-33.1>
- Catling, P. M., and V. R. Brownell.** 1999. The alvars of the Great Lakes region. Pages 375–391 in *Savanna, Barren and Rock Outcrop Communities of North America*. Edited by R. C. Anderson, J. S. Fralish, and J. M. Baskin. Cambridge University Press, Cambridge, United Kingdom.
- Catling, P. M., P. M. Catling, J. Cayouette, M. Oldham, B. Ford, C. Hamel, and C. Friesen.** 2014. Canadian alvars and limestone barrens: areas of “Special Conservation Concern” for plants? *Canadian Botanical Association Bulletin* 47: 9–11. Accessed 19 June 2017. <http://www.cba-abc.ca/bulletinMarch2014.pdf>.
- Catling, P. M., J. E. Cruise, K. L. McIntosh, and S. M. McKay.** 1975. Alvar vegetation in southern Ontario. *Ontario Field Biologist* 29: 1–25.
- Catling, P. M., H. Goulet, R. Bennett, and B. Kostiuk.** 2010. Orthopeterans (Orthoptera), ground beetles (Coleoptera: Carabidae) and spiders (Araneae) in burned and unburned alvar woodlands—the importance of postfire succession to insect diversity. *Journal of the Entomological Society of Ontario* 141: 27–37. Accessed 19 June 2017. http://www.entsocnt.ca/uploads/3/0/2/6/30266933/catling_et_al_final.pdf.
- Jalava, J. V.** 2007. Alvars of the Bruce Peninsula: a consolidated summary of ecological surveys. Prepared for Parks Canada, Bruce Peninsula National Park, Tobermory, Ontario, Canada.
- Konigsson, L.-K.** 1968. The Holocene history of the Great Alvar of Oland. *Acta Phytogeographica Suecica* 55 (suppl. 1): 1–172.
- Macpherson, A. H.** 1971. Roland E. Beschel. (1928–1971). *Arctic Institute of North America* 24: 316. <https://doi.org/10.14430/arctic3148>
- Manitoba Alvar Initiative (Neufeld, R., C. Friesen, and C. Hamel).** 2012. Alvars in Manitoba: A Description of their Extent, Characteristics & Land Use. Nature Conservancy of Canada, Manitoba Region, Winnipeg, Manitoba and Manitoba Conservation and Water Stewardship. Accessed 19 June 2017. <http://www.natureconservancy.ca/assets/documents/mb/2012-Alvar-Initiative-FINAL-Report-PUBLIC-DISTRIBUTION-Jan-2013.pdf>.
- Reschke, C., R. Reid, J. Jones, T. Feeney, and H. Potter.** 1999. Conserving Great Lakes alvars. Final Technical Report of the International Alvar Conservation Initiative. Nature Conservancy of Canada. Accessed 19 June 2017. <https://archive.epa.gov/ecopage/web/html/index-10.html>.
- Rosen, E.** 2006. Alvar vegetation of Öland—changes, monitoring and restoration. *Biology & Environment* 106B: 387–399. Accessed 19 June 2017. <http://www.jstor.org/stable/20728609>.
- Schaefer, C. A., and D. W. Larson.** 1997. Vegetation, environmental characteristics and ideas on the maintenance of alvars on the Bruce Peninsula, Canada. *Journal of Vegetation Science* 8: 797–810. <https://doi.org/10.2307/3237024>

Received 2 June 2017

Accepted 19 June 2017

Book Reviews

Book Review Editor's Note: *The Canadian Field Naturalist* is a peer-reviewed scientific journal publishing papers on ecology, behaviour, taxonomy, conservation, and other topics relevant to Canadian natural history. In line with this mandate, we review books with a Canadian connection, including those on any species (native or non-native) that inhabits Canada, as well as books covering topics of global relevance, including climate change, biodiversity, species extinction, habitat loss, evolution, and field research experiences.

Currency Codes – CAD Canadian Dollars, USD US Dollars, EUR Euros, AUD Australian Dollars, GBP British Pound.

BOTANY

Vascular Plants of Alberta, part 1: Ferns, Fern Allies, Gymnosperms, and Monocots

By John G. Packer and A. Joyce Gould. 2017. University of Calgary Press. 281 pages, 34.95 CAD, 34.95 USD, Cloth. Also available as a paperback, PDF, or E-book.

Alberta, including 660 000 km² and six major ecozones, is a diverse Canadian province. Almost 2000 species of vascular plants have been recorded (almost 1500 native). This book covers 524 species, roughly one-quarter of the vascular flora, including the ferns and their allies, evergreen or conifer trees and the monocots (which can be conveniently viewed as vascular plants with parallel leaf venation). The book is designed to assist with information about Alberta's flora by including keys and descriptions of new species added since the second edition (1959) of the *Flora of Alberta* by Ezra H. Moss, which was updated by John G. Packer and published in 1983. It is entirely alphabetical; the species are listed alphabetically within genera, genera alphabetically within families, and families alphabetically within major groups. Infrataxa (subspecies and varieties) are included in the text for species.

A vast amount of new and current information here has been made possible through the Flora of North America project (FNA), which was designed to create a complete set of 30 volumes including all the 21 000 species growing outside of cultivation in North America. With the completion of much of this project and the continuing work of Alberta botanists, it has been possible to distil the information on Alberta from the FNA and to provide an update to it.

The authors are well qualified to write about the Alberta flora. John Packer was curator of the herbarium at the University of Alberta from 1958 to 1988 and an author of articles and books on arctic and alpine regions as well as serving as an expert on the Alberta flora. Joyce Gould, an adjunct professor at the University of Alberta, has been responsible for the overall coordination of science in Alberta Parks and is well known for her work on species at risk. The keys to *Carex* were provided by Bruce Ford and Bill Crins, both internationally renowned experts on that difficult group. Peter Achuff, well-known botanist of the Waterton area of Alberta, helped in providing distributional data. Based on the skills of these and other people involved, the book is as good as one would expect it to be.

The following Albertan species are missing. Of the additions to the flora of Alberta since 1983 listed by Fabijan (2015a,b), only four are not included here: *Blysmopsis rufa* (Hudson) Oteng-Yeboah, *Botrychium boreale* J. Milde, *Cystopteris laurentiana* (Weath.) Bladsdell, and *Elodea canadensis* Michx. All are based on specimen vouchers and should presumably be added. *Allium geyeri* S. Watson var. *geyeri* was excluded from the flora of Alberta by Choi and Cota-Sanchez (2010) based on misidentification, but *Allium stellatum* should be added (Choi and Cota-Sanchez 2010). *Juncus interior* Wieg. was not included although it is indicated for Alberta in the text in FNA (Brooks and Clements 2000), but it is not shown on the FNA map, perhaps explaining its omission. A detailed map for this species in Alberta is available in Catling and Spicer (1987). *Phragmites australis* (Cav.) Trin. ex Steud. subsp. *australis* has been found in Alberta at Grande Prairie (S. Landhausser, determined by P.M. Catling, Agriculture and Agri-Food Canada, DAO). *Potamogeton amplifolius* Tuckerman was recently reported as new to Alberta (Crisfield 2016).

I was pleased to see hybrid *Botrychium*, *B. ×water-tonense* mentioned under *B. hesperium* (p. 44), but there is some question about its sterility (Ahrensleger and Lesica 1998). Other hybrids are similarly mentioned in the text of one of the parental species. A recently reported orchid hybrid, Kostiuik's Hybrid Calypso (*Calypso ×kostiukiae*) is not included (Catling 2012).

The book is available as a free open access e-book (http://dspace.ucalgary.ca/bitstream/1880/51799/1/9781552386835_web.pdf) or can be ordered as a print version from the publisher (ucpress@ucalgary.ca). The PDF has the advantage of being searchable. This makes the PDF helpful because the print copy does not have an index. It would have been useful to have a list of species that have been reported but rejected and the reasons for rejection.

One of the great values of this publication lies in the fact that it is current, complete, and authoritative. It will be useful to botanists, landscape managers, researchers,

and anyone who needs reliable information. Congratulations to the authors.

Literature Cited

Ahlenslager, K., and P. Lesica. 1996. Observations of *Botrychium watertoniense* and its putative parent species, *B. hesperium* and *B. paradoxum*. *American Fern Journal* 86(1): 1–7. <https://doi.org/10.2307/1547602>

Brooks, R. E., and S. J. Clements. 2000. 1. *Juncus* Linnaeus, Sp. Pl. 1: 325. 1753. Gen. Pl. Ed. 5: 152. 1754. In *Flora of North America North of Mexico*, Vol. 22, Magnoliophyta: Alismatidae, Arecidae, Commelinidae (in Part), and Zingiberidae. Edited by Flora of North America Editorial Committee, 1993+. http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=222000145.

Catling, P. M. 2012. A new infraspecific *Calypso* hybrid. *Native Orchid Conference Journal* 9(1): 1–6, Figures 1 and 2.

Catling, P. M., and K. W. Spicer. 1987. The perennial *Juncus* of section Poiophylli in the Canadian prairie provinces. *Canadian Journal of Botany* 65: 750–760. <https://doi.org/10.1139/b87-100>

Choi, H. J., and J. H. Cota-Sanchez. 2010. A taxonomic revision of *Allium* (Alliaceae) in the Canadian prairie provinces. *Botany-Botanique* 88(9): 787–809. <https://doi.org/10.1139/B10-056>

Crisfield, V. 2016. Two new species for Alberta. *Iris (The Alberta Native Plant Council Newsletter)* 78: 1–3.

Fabijan, D. 2015a. Alberta plant list is longer now. *Iris (The Alberta Native Plant Council Newsletter)* 76: 1,5.

Fabijan, D. 2015b. New vascular plant species in the province of Alberta. *Iris (The Alberta Native Plant Council Newsletter)* 76: 2–5.

Moss, E. H. [updated by J.G. Packer]. 1983. *Flora of Alberta*. Second edition. University of Toronto Press, Toronto, Ontario, Canada.

PAUL M. CATLING
Ottawa, ON Canada

ZOOLOGY

Ecology of Salmonids in Estuaries around the World: Adaptations, Habitats, and Conservation

By Colin D. Levings. 2016. University of British Columbia Press. 388 pages, 75.00 CAD, Cloth.

Owing to a long history of human interaction with salmonids, this taxonomic family is lauded among the most charismatic fishes. The migration of many salmonid species between freshwater and the ocean facilitates their rapid growth and has long provided essential ecosystem and cultural services in northern temperate environments, and now also in the southern hemisphere where they have been widely introduced. Although most of the migratory salmonid’s life is spent in the marine or freshwater environments, Colin Levings’s new book, *Ecology of Salmonids in Estuaries Around the World*, emphasizes the importance of the estuary, an often-overlooked ecotone between salt and fresh waters that salmonids must navigate on their journeys from and to their freshwater spawning habitat. The book considers all facets of the salmonid’s life and the influence of the estuary, ranging from physiological and behavioural changes while transitioning from salt to fresh water (and vice versa) to life history metrics such as growth and survival. The book draws on diverse literature focussing on many different species of salmonids and generates many original tables and figures in support of its various themes, including species diversity and distribution, osmoregulatory adaptations, and salmonid harvest and conservation.

Although the estuarine residency of salmonids represents a relatively brief period in the life of these fishes, Levings’s book magnifies this period and addresses the diverse challenges posed by the estuary, even conceptualizing estuaries as ecological bottlenecks, where mortality – and therefore natural selection – operate on

many species. Regardless of whether readers approach this text with an appreciation of the biological role of estuaries, they are certain to close the book with a greater understanding of their importance. There are many reviews and books focussed on marine and freshwater lives of salmonids and Levings posits that there is lacking a general reference on salmonids in estuaries.

Most estuaries are situated close to human settlements and estuaries are a particularly sensitive habitat worldwide, now considered to be among the most degraded ecosystems on the planet. Although the narrow focus of this book on migratory salmonids during the portion of their lives passed only in estuaries may appear to be a topic better suited to a review paper, the book expands so broadly on the topic that it is clear that such a paper would not do justice to the subject. According to Levings, 18 salmonid species are known to use estuaries; in addition to being emblematic species of cultural and economic interest, the diversity and distribution of salmonids in estuaries also make them a suitable candidate species for studying estuarine biology. Indeed, the underlying theme of Levings’s book is using salmonids as a case study for a broader understanding of estuaries themselves. In fact, the book makes an excellent reference on estuary habitat in general (albeit temperate estuaries). Hopefully, the specificity of the subject does not deter anybody from picking up the book because there is much to be learned about both fish ecology and physical oceanography limnology from this book, which will interest many readers, even those without any specific affinity for salmonids.

Salmonids of native and wild origin lead the book around the world, even into the Southern Hemisphere where they have been widely introduced (e.g., Argentina, Chile, New Zealand, Kerguelen) to explore the chemical, physical, and biological characteristics of estuaries “from a salmonid’s eye view”. In this sense, it is an excellent general text on estuaries marrying the biotic and abiotic environments.

As focal species, salmonids have broad appeal to both scientists and the public. This work is best suited, however, to those with an interest leaning towards the scientific realm given the extensive detail and careful citation of works within. Nonetheless, there is also frequent definition of terms throughout the book (e.g., ecological indicators, p. 207; marine protected areas, p. 225), ensuring accessibility of the entire text for readers of varied interests, including both natural history enthusiasts and scientists from other disciplines (e.g., physical oceanographers or limnologists).

It is clear that Levings’s long career dedicated to researching estuarine biology contributes greatly to the detail contained within the book, with consideration given to nearly every possible biotic and abiotic factor within the estuary that might be encountered by salmonids, including predation, competition, pollution, salinity, and temperature. There is significant use of published literature on salmonids in estuaries used as support throughout the book. However, there is also consideration given to areas lacking sufficient research about which the author provides some speculation based on his experience and understanding of salmonids in fresh or salt water. The data-deficient topics the book identifies, such as effective methodology for restoration of estuaries and the potential for designating estuaries as protected areas, call for further research,

potentially making it an important reference for early career salmonid researchers or others developing research agendas on the topic.

The conclusion is nicely bookended with reference to one of the author’s own 1984 works reviewing the science of estuaries, calling for a test of the hypothesis that juvenile salmonids are not dependent upon estuaries (p. 284). Although the scope of the book extends well beyond this specific hypothesis, it is evident that the years have been kind to that particular question, advancing the overall state of research on salmonids. There has clearly been a considerable shift in focus towards research in estuaries during Levings’s career, and readers will see firsthand by noting the recency of most literature cited in the book. The state of the research is still only in its early-mid phase with much more to learn and apply about estuaries to ensure their conservation. Evidently, this book represents a sort of mid-term review rather than a final examination of the subject, a reference that will hopefully direct further research towards estuaries. Indeed, Levings offers readers some inspiration should they be developing their own research agenda and interested in exploring estuaries, including studying cumulative effects of impacts on salmonids making the transition through estuaries and developing more comparative studies among estuaries. The book will hopefully instigate another push towards the study and protection of estuaries as these sensitive habitats clearly need greater focus to ensure the conservation of many species and particularly salmonids.

ROBERT J. LENNOX

Fish Ecology and Conservation Physiology Laboratory, Department of Biology, Carleton University, Ottawa, ON, Canada

Heart of a Lion: A Lone Cat’s Walk Across America

By William Stolzenburg. 2016. Bloomsbury Publishing. 256 pages, 27.00 USD, Cloth.

I’ve had a lifelong love and fascination of Cougars (*Puma concolor*), also called Mountain Lions, Catamounts, Pumas, and Panthers, among dozens of other names. So perhaps it wasn’t surprising that I could not put *Heart of a Lion* down once I started reading it. It is a fascinating account, tracing a Cougar from its probable origin in the Black Hills of South Dakota to its death (by vehicle) in southwestern Connecticut, about 2000 miles away – including a point when he was only 23 miles, a two-nights’ jaunt, from New York City (p. 172). This is the longest known terrestrial dispersal in the animal kingdom and Will Stolzenburg does a masterful job of weaving in the stories of all of the players, from local police to homeowners to wildlife experts, involved in documenting this young male Cougar’s nearly two-year odyssey.

In addition to this individual Cougar and his cult following, Stolzenburg weaves in a treasure trove of infor-

mation about Pumas from human’s shameful history of eradicating them, to protecting them, to the current overhunting taking place in many western states. In fact, Stolzenburg used so many sources in researching this book, that he generated a website, www.lionstrek.com, to produce a detailed list of references complementing the selective bibliography. Yet even with all the technical and comprehensive information that is provided, it is a very understandable account. And in addition to being an enthralling read, it’s also a fabulous resource for information about Cougars and humans’ (mostly negative) history with them.

One theme that resonates throughout the book is the bizarre and seemingly ubiquitous sightings of ‘eastern cougars’, despite the clear majority of them not being confirmed and there being no breeding population of the cats in the East except in south Florida. There are people, some of them even affiliated with academia,

who swear to the presence of Cougars despite the contrary evidence that no verified picture or physical proof (e.g., road-kill) of a big cat has come from this region in nearly a century.

That was the case until 11 June 2011, when a 139-pound Mountain Lion was hit and killed by a car on a Connecticut parkway. Initially there was speculation that this animal was a remnant survivor of the 'eastern cougar' race, but an amazing DNA trail quickly led to the discovery of this animal taking a six-state journey from the Black Hills of South Dakota to the Northeast U.S.

Even though I was aware of this particular Cougar and his travels from the internet and professional associations, I was still captivated reading *Heart of a Lion* and Stolzenburg's retracing of this lion's two-year journey, as articulated on the book's cover, "from his probable birthplace in the Black Hills, across the Great Plains and the Mississippi River, through Midwest metropolises and remote northern forests, to his tragic final resting place upon Connecticut's Gold Coast. Along the way, the lion traverses lands with people gunning for his kind, as well as those championing his cause". This Cougar travelled as if to defy people's groupings of natural objects and places. Its sign, verified six times through DNA testing, was picked up 15 times over 18 months, showing clearly that if a Cougar is there, sign will be found. Despite travelling past thousands of people, including through many residential areas, he never threatened a human soul nor caught scent of a female Mountain Lion (p. 198).

The book's cover jacket notes that "*Heart of a Lion* is a story of one heroic creature pitting instinct against towering odds, coming home to a society deeply divided over his return. It is a testament to the resilience of nature, and a test of humanity's willingness to live again beside the ultimate symbol of wildness". This predator – like others – can also bring out the worst in certain people, such as state legislator Betty Olson (Republican-South Dakota; pp. 135–137, 202), who has vilified them with unbridled fear, delusion, hatred, and outright uneducated reactions to a supposedly dangerous animal that rarely hurts humans. In fact, one is statistically more likely to get hit by lightning, killed in a deer-vehicle accident, killed by a bee sting, heat wave, or deep freeze, or die from a host of other natural factors than to get attacked by a Cougar. Yet, many states have laws that allow their destruction even where they do not currently live. This is the case despite recent peer-reviewed research suggesting that Mountain Lions make it safer for humans because they prey on deer, which kill about 200 people a year nationwide, mostly through vehicle accidents. In fact, Gilbert *et al.* (*in press*) found that a recovered Cougar population in the eastern United States could prevent 21 400 human injuries, 155 fatalities, and \$2.13 billion in avoided costs within 30 years of establishment! Ironically, that article also states that South Dakota, which has recently hammered its lion population with increased human hunting, saves \$1.1 million a year with their recently estab-

lished Cougars. In the chapter *The Deer Shepherd*, Stolzenberg does a great job of illustrating the importance of maintaining large predators (Coyote size and up), and specifically Mountain Lions, toward the functioning of a healthy ecosystem with reduced deer densities.

Another main character in the book is Chris Spatz, President of the Cougar Rewilding Foundation (CRF), who was skeptical of 'native' Mountain Lions inhabiting the East, based on his years of investigating reported "sightings" that turned out to be everything but Pumas. He and the CRF collectively put out dozens of remote wildlife cameras but failed to document a single Catamount. Spatz did obtain plenty of images of house cats (many of which were initially believed to be Pumas), dogs and their tracks, Bobcats, bears, Coyotes, deer, turkeys, and many of the other common animals living in the East. Re-evaluating his goals once Cougars were found to be nonexistent in the Northeast, Spatz and his organization now (and, I would argue, appropriately) advocate for lion restoration to the East. He (and other carnivore advocates) chastises Midwestern states for killing Cougars because they enter towns and sends them press clippings of California's new law (pp. 206–207) requiring non-lethal procedures when lions enter populated areas. California's progressiveness and saneness give one hope that other states will follow. So, too, does research from Washington State University (pp. 139–140) showing that the more Cougars are killed, the more livestock and pets were attacked – due to the social chaos of the surviving lions.

The Black Hills are the source of many of the eastward dispersing Cougars which have left their birthplace in search of females and a territory of their own. All the other documented long-distance dispersers have also died as a result of human actions, mainly through vehicle accidents and gun-shots. Virtually all of them have been young males. For instance, another Cougar that made it to Chicago, Illinois in 2008 was heartbreakingly gunned down by police "to protect public safety" (pp. 97–103). Spatz and his organization lament that South Dakota and other prairie states, with their hostile policies toward Mountain Lions, are preventing Midwestern and eastern recovery of these big cats.

Overall, I really enjoyed reading this story about one of my favourite animals although, admittedly, I became sad and angry at the many depictions – starting all the way back with Ben Lilly in the late 1800s and early 1900s – of how people have treated Mountain Lions as vermin and exterminated them including right up to modern times. I only have a couple of very minor complaints about the book. First, there is only one black and white picture throughout. I thought it would have been cool, if possible, to have pictures and documentation of the animal throughout its eastern journey including trail-camera pictures and stills from videos. Also, the cover insert had a great map of the cat's travels but there were no localized maps or figures within the book as it went from state to state; rather, there were only text descriptions, albeit very detailed and meticulous.

As I write this in November 2016, there is good news on the Puma front: a female Florida Panther – the local lingo for *Puma concolor* living in south Florida – has crossed the Caloosahatchee River to the north and may be the source for a population expansion of Panthers to central Florida. This is welcoming news for sure, but too little to celebrate until state wildlife agencies nationwide start recovering carnivores like they have for numerous other now common “game” animals. Reading *Heart of a Lion* gives me hope that lions will continue trailblazing to the East and state wildlife agencies and their citizens will do a better job of welcoming them, including reintroducing them to old haunts. One sug-

gestion I have is for environmental groups to purchase many copies of this book and to give to all Midwestern and eastern legislators to show how ecologically, ethically, and culturally important having Mountain Lions on the landscape is!

Literature Cited

Gilbert, S. L., K. J. Sivy, C. B. Pozzanghera, A. DuBour, K. Overduijn, M. M. Smith, J. Zhou, J. M. Little, and L. R. Prugh. *In press*. Socioeconomic benefits of large carnivore recolonization through reduced wildlife-vehicle collisions. *Conservation Letters*. <https://doi.org/10.1111/conl.12280>

JONATHAN (JON) WAY

Eastern Coyote/Coywolf Research, Osterville, MA, USA

OTHER

Blooms. An Illustrated History of the Ornamental Gardens at Ottawa's Central Experimental Farm

By Richard Hinchcliff. 2016. Sanderling Press. 304 pages, 35.00 CAD, Cloth.

Richard Hinchcliff's new book, *Blooms, An Illustrated History of the Ornamental Gardens at Ottawa's Central Experimental Farm* is, first and foremost, gorgeous. It is jam-packed with photographs, including contemporary images and archival material. The older photos include hand-coloured images, which have a lovely, painterly quality. Most of the recent photos come from Hinchcliff himself, who is clearly a technically-expert and artistically-talented photographer. Several accomplished botanical illustrators have worked at the Experimental Farm over the years, and their work graces the pages of the book as well.

The text itself can be divided into two sections: a history of the development of the gardens, and presentation of the current gardens.

The history starts with the founding of the gardens by William Saunders in 1886. Hinchcliff traces the development of ornamental plant research program, including the contributions of Saunders, his son Percy, James Fletcher, William Macoun, Isabella Preston, Felicitas Svejda, and many others. While they each had their favourite plants, collectively their focus never wavered from developing hardy, beautiful, and sometimes tasty, plants for Canadian gardens. In addition to introducing us to their work, Hinchcliff shows us a bit of the social lives of the researchers at the gardens. We learn about the musical Saunders family and Macoun's poetry. Isabella Preston, a highly regarded (and honoured) horticulturist both in Canada and abroad, was a prolific author of books and articles, but eschewed publicity and avoided speaking engagements whenever possible.

Hinchcliff also gives us a sense of the garden's role as an attraction for Ottawa residents and tourists alike. Popular as the gardens are today, they clearly played an even more vital role in Ottawa society in decades past. Getting people to and through the garden grounds was a central goal in many civic improvements. Further, the botanical expertise embodied in the gardens staff

was drawn on in planning other floral projects, including William Lyon Mackenzie King's Kingsmere in Gatineau. Indeed, in the era in which the Experimental Farm was established, encouraging gardening as a pastime was seen as a way to boost morale, and fight Bolshevism and foreign ideals!

The second part of the book changes focus, shifting from the botanists to the botany. Short chapters on each of the main collections are presented: roses, peonies, lilies, lilacs, crabapples, a dozen in all. Hinchcliff reviews the work done on each group at the Experimental Farm, and highlights the varieties that can be found in the gardens today. Some of the details from the historical section are repeated – not enough to become repetitive, but enough that you could read the chapters out of order without confusion.

There's a bit more botanical information here, including illustrations of the different types of peony blooms, guides to lilac colours and flowering time, and a checklist of roses released from the Experimental Farm. That said, *Blooms* remains primarily a celebration of the gardens, but with more than enough details to entice us to (re)visit the gardens to chase down some of the plants he describes. Hinchcliff very helpfully provides maps of the gardens at the end of the book, to encourage us to do just that. And if you do, you may also be interested in Hinchcliff's previous book, *For the Love of Trees*, a guide to the trees of the Central Experimental Farm arboretum, co-authored with Roman Popadiuk.

At \$35.00, *Blooms* is a steal. It is not available from general online booksellers, but you may purchase a copy directly from the Friends of the Central Experimental Farm, with details at their website: friendsofthefarm.ca. Richard Hinchcliff is a long-time volunteer and current board member with this group.

TYLER SMITH

Agriculture and AgriFood Canada, Ottawa, ON, Canada

Best Places to Bird in British Columbia

By Russell Cannings and Richard Cannings. 2017. Greystone Books. 212 pages, 22.95 CAD, Paper.

The father and son duo of Richard and Russell Cannings are on the road again, birding throughout their home province and taking us along for the ride. Dedicated birders will already be familiar with their nearly 500-page tome, *Birdfinding in British Columbia* (published in 2013 by Greystone Books), which in turn built on earlier guidebooks by other authors. Their most recent book, *Best Places to Bird in British Columbia*, will be more appealing to the general naturalist and less intimidating to beginning birders.

The Cannings have chosen 30 of their favourite birding locations in B.C. While their chosen sites represent all the ecological regions in this vast province, it is more heavily weighted to the southern part, because that's where most birders live or visit. However, they do include some remote sites, such as Triangle Island (off the northwest tip of Vancouver Island), Haida Gwaii, and the Haines Highway in the very northwestern triangle of the province.

Each of the 30 destinations has its own chapter and follows a similar format, starting with a short narrative of what's special about the area and why birders should go there. This is followed by the bulk of the chapter, titled "Birding Guide", which details how to get to the site (including "sub-sites"), a brief description of the habitat, what common birds to expect as well as what rarities have been recorded, when the best time to go is but also what might be seen if you are stuck with visit-

ing in other seasons, too. There is an excellent sidebar called "Getting There" with a clear, simple map and instructions for finding the right roads. All chapters have a photo of a species that you can expect to see in the area, and occasionally a photo of typical habitat.

The authors share personal anecdotes, where appropriate, but don't overdo it. There are also touches of light humour, as when they are describing Iona Island in the lower mainland, where millions of gallons of sewage pour into the Strait of Georgia every day, and note that "The sad thing is, I know some of you read that last passage and get sincerely excited" (p. 51).

Perhaps it was a function of the lead time to getting published, but the authors perpetuate the popular myth that Snowy Owls that irrupt south, for example to Boundary Bay at Vancouver, leave the north to escape low lemming and other rodent populations, arriving exhausted and starving. Recent research is showing that the story is much more complicated—the biggest irruptions may actually be the result of high lemming numbers during the previous breeding season resulting in a large number of birds competing for food, and many being forced to forage farther afield.

This book is an excellent primer for birders who are new to the province or novice birders who might be overwhelmed by the larger guidebook.

CYNDI M. SMITH

Canmore, AB, Canada

The Carbon Code: How You Can Become a Climate Change Hero

By Brett Favaro. 2017. John Hopkins University Press. 224 pages, 22.95 USD, Cloth.

The Carbon Code is for readers frustrated with the slow pace of political will when it comes to taking action on climate change. Brett Favaro, a marine scientist at Memorial University of Newfoundland in St. John's, fills his book with actions that individuals can take today to lower their carbon footprint. By adopting a personal carbon code of conduct, a 'do as little harm as possible' approach to daily life that aims to cut down on total greenhouse gas emissions, we can all be models of how living sustainably can work for the average person. Most of the information in this book, from the value of biking to work or the benefits of LED light bulbs, will not be new to readers already dedicated to a sustainable lifestyle. This will be most useful for readers who are not yet climate change activists, but who are genuinely interested in incorporating sustainability into their daily lives.

The Carbon Code is structured in three parts. The first covers the science of climate change, the widespread and disastrous implications for the planet, and how individuals can make a difference in decreasing

global greenhouse gas emissions (and by extension, slowing down climate change). Favaro wraps up Part I by introducing his carbon code of conduct that consists of four R's: *Reduce* carbon output as much as possible; *Replace* carbon intensive activities with less carbon intensive activities; *Refine* the activity to get the most out of the carbon that is used; and *Rehabilitate* the atmosphere by purchasing carbon offsets (p. 51).

Part II details four areas of daily life that can be modified to follow the carbon code of conduct: electricity, transportation, diet, and long-distance travel. In each chapter, we learn about more (or less) simple actions that homeowners can take to lower their individual carbon footprint, including: install a smart thermostat or a solar panel; consider purchasing an electric car; take public transit or, best of all, bike or walk to work; stop eating beef and other ungulates; reduce air travel in favour of trains, buses, and carpooling for vacations; and avoid taking a cruise. Never does Favaro bully or shame the individual into any of these actions. He is unfailingly positive throughout the book and consistent-

ly boosts the economic benefits to the individual alongside the environmental benefits.

The last section is perhaps the most useful and unique of *The Carbon Code*. It first outlines how to “win the conversation” for climate change action against various types of skeptics and deniers, and then provides an explanation of nine pro-climate policies that coincidentally are also good for the economy, our health and our communities. Throughout this section (and the book), Favaro purposefully empowers the reader to advocate for these sustainable initiatives, even if they are not an ‘expert’ on climate science or economics. As the author stresses, a great majority of credible scientists agree that climate change is occurring at an unprecedented rate, so to argue in favour of lowering greenhouse gas emissions is to be on the right side of history.

Overall, *The Carbon Code* makes a strong case that climate change is an urgent problem that must be tackled immediately by every individual on a daily basis. Some sections are a little weighed down by detailed explanations that sometimes become pedantic, and a few figures or references to useful websites and other resources would have made it more accessible. Fortunately, Favaro’s strident positivity and hope shine through and carry the reader along to the important final chapters, where realistic policy changes are discussed. This would be an ideal book for anyone who would like to learn about climate change and what they can do as an individual to lower their carbon footprint.

EMMA BOCKING
St. John’s, NL, Canada

Ice Blink: Navigating Northern Environmental History

Edited by Stephen Bocking and Brad Martin. 2017. University of Calgary Press. 526 pages, 41.95 CAD, Paper or E-book.

This book is about the effect of southerners on the “north” (mostly, Nunavut, Nunavik, Northwest Territories, and Yukon) and, to a lesser extent, the impact of the north on southerners. Chapters cover Reindeer management, bush planes, mineral exploration, northern nutrition, the DEW line, ghost towns, environmental contamination, and the politics of climate change. Most of the chapters have interest for those concerned about the north and all are well-written and (for social sciences, especially) refreshingly free of jargon. A short final chapter summarises and attempts to synthesize the diverse threads of the book, but it is not entirely convincing: the book remains a collection of one-offs. Do not be daunted by the more than 500-page length: about

100 consist of footnotes. Readers of *The Canadian Field-Naturalist* should note there is little natural history. The index names only three animals: Polar Bear (of course!), Reindeer/Caribou, and Walrus. There is mention of generic ‘geese’ and ‘whales’. A whole chapter on northern contaminants – a very welcome surprise – for which much research has been conducted on birds and marine mammals, fails to mention any actual species sampled. It is almost as though the authors of this collection are scared of biology. A good read for northern enthusiasts, but not recommended for naturalists.

TONY GASTON
Ottawa, ON, Canada

Protecting the Planet: Environmental Champions from Conservation to Climate Change

By Budd Titlow and Mariah Tinger. 2016. Prometheus Books. 587 pages, 26.00 USD, Cloth, 11.99 USD, E-book.

A few years ago, “My Big, Fat Greek Wedding” burst onto the screen. It proved to be a very popular film. Perhaps you remember it? I’m reminded of it because *Protecting the Planet* is a big, fat American book on climate change. It deserves to be even more popular than the movie, and, hopefully, will be remembered much longer. The authors are a father-in-law/daughter-in-law team: Budd Titlow draws on an extensive background in biology as well as years of experience as a field-naturalist, writer, blogger, and teacher of related topics at Florida State University; Mariah Tinger is an educator in environmental stewardship and management and a teaching fellow in related topics at Harvard University. Their message and purpose, of course, are much more important than those of the movie – which is not to demean the movie in any way – and we will forget them at our collective peril.

The subtitle, *Environmental Champions from Conservation to Climate Change*, provides a mini-review of the contents of the book. While climate change is

the main theme and concern, the authors have chosen to provide a chronological overview of changes to the climate and biogeography of America. The book has 31 chapters organized into five parts, the first being an introduction to climate change, each of its six chapters titled in the form of a question, beginning with the definition of climate change, then its history, the how of it, proof of it, and its present-day impacts. The final chapter of Part One is a brief reply to the question, what can we do about it? This question forms a guiding theme throughout the book and receives fuller treatment in its conclusion.

Parts Two and Three cover 200 years of the US environmental movement from 1800 to today. Their potted history of America provides the substrate for the authors’ “story for the ages”, which involves numerous “heroes”, the environmentalists whose efforts are traced through the ebb and flow of environmental movements, all linked to major social, economic, and political factors. Many topics are noted in over a dozen chapters

covering decadal periods of change characterized by terms familiar to any student of American history: Manifest Destiny, the Civil War of 1849–1869, the rise of industrial America, 1870–1900, and so on. The earlier periods witnessed the growth of conservation movements, with climate change becoming an increasingly important public issue in the 1980s. Each period is characterized by a major element or overarching event that moves the environmental movement either backward or forward. The former is characterized by world events such as World War II and conservative domestic politics (the Reagan and Bush years, for example) while the latter coincides with periods of high interest in the environment, such as the 1960s, and liberal administrations. Increasingly, climate change—the developing science and the conflicting views of that science—takes centre stage. The authors recount these themes largely through the efforts of their chosen heroes and major efforts at dealing with climate change, such as the series of COP (Conference of the Parties) meetings that resulted in the Kyoto, Paris, and other agreements. Part Three ends with a brief attempt to assess the future of climate change. The authors “firmly believe that the time is ripe for climate-change solutions” to be born from “the hopeful and forceful voice of the masses...” (p. 336).

Part Four is a paean to the heroes of today, “who they are and what they have done”, in the words of this section’s subtitle. The people presented here are grouped into six chapters depending on their professions, whether scientists, advocates, politicians, artists/activists, and so on. The focus is biographical, based on interviews and personal stories, but always includes discussion of key ideas and contributions. We have met many of these people in earlier chapters; in fact, Parts Two and Three are rife with cross-references to the mentions of them in Part Four. Thus, a discussion of a scientist’s break-through research in Part Three might conclude with the statement that we will learn more about that scientist in the appropriate chapter of Part Four. The purpose of this catalogueish approach seems to be two-fold: to provide further biographical background on the hero and thereby to encourage readers to emulate their efforts or, at least, to feel some hope. The result, however, is that the book is a compendium of short pieces of information, each with its own headline. From a glass-half-empty viewpoint, this can make reading the book a bit of a slog: one gets nicely hooked into some detail, only to be told that more on this person or that event is coming up later. Very often the next short topic is not related directly, but only within the

theme of the chapter. The glass-half-full viewpoint is an appreciation of the great deal of information presented in an accessible way, introducing the reader to cleanly described ‘bites’ that can then be followed up through the copious end-notes or searches on the Internet. The authors used the Internet a great deal, judging by the notes, but also interviewed many of the people whose efforts they celebrate.

Part Five focusses, as promised, on “Finding Solutions”. The first of three chapters is optimistically titled “How the Climate-Change War Can Be Won”; it opens with a rather convoluted metaphor through which the authors assert that “climate change may just turn out to be our staunchest ally”. We’ve fouled our planetary nest and the climate is issuing its “loud wake-up call” that the time has come to clean up (p. 427). The authors call for a “grand paradigm shift” through which everyone will recognize the need to act (p. 429). They then propose that the United States is morally bound and fiscally able to lead the way and offer a series of strategies they believe are necessary for that leadership to be effective, first within the US and subsequently in the world at large. The final chapter promotes strategies for the world, some already in train, some controversial. But all rely on global cooperative efforts that seem to this reader at least to be much more difficult to accomplish than the hopeful evocation can achieve.

If you want an introduction to the topic and the key players, then this is your book. It could be useful in the classroom and profitably read by any concerned or interested person looking for a jargon-free account of the many aspects of this issue. The book has an extensive table of contents and is well indexed, features that help in navigating the book’s many chapters; its 80 pages of notes are organized by chapter number and title. The book focusses on the United States—although Canada’s Naomi Klein gets good mention—and is imbued with what seems to this reviewer to be a very American ethos, that climate change can be addressed if only we all pull together and give it our best efforts. There are moments when this seems naïve, but the authors do present myriad approaches being taken and advocated. Climate change denial cannot be denied, and the authors address it at various points, but the focus is on hope, the need for immediate action to gain future success. The dark underbelly of such optimism, however, is that if it fails to achieve its goals, we humans as a species are pretty much doomed.

BARRY COFTAM

Ottawa, ON, Canada

Alexander Wilson: Enlightened Naturalist. Aperçus: Histories Texts Cultures Series

Edited by Edward H. Burt, Jr. 2016. Bucknell University Press and Rowman & Littlefield. 202 pages, 80.00 USD. Cloth, 39.99, Paper or E-book.

Alexander Wilson is presented here as the father of American ornithology. One might wonder why John James Audubon does not have this distinction, for Au-

dubon overshadows Wilson, enjoying a larger reputation, owing at least in part to his name having been adopted by one of the premier conservation societies

of America and, indeed, the world. Audubon's larger stature is conceded by the authors of this book, but their work goes some way to justifying and raising awareness of Wilson's role. Indeed, the claim is made that Wilson inspired Audubon by example. But you'll have to wait awhile – if you read the book from beginning to end – to get to the meat of their argument. First, however, we must learn of Wilson's life in Scotland, his emigration to the United States, and his poetic descriptions of life in the early 19th century eastern forests.

Alexander Wilson: Enlightened Naturalist is an outcome of a one-day symposium on Wilson held in April 2014 at Ohio Wesleyan University. It was organized by one of Wilson's biographers, Edward H. Burt, Jr., who edited the proceedings. Burt taught at Ohio Wesleyan, overcoming his life-long physical limitations to become a keen field ornithologist and inspiring professor who, sadly, did not live to see this lovely volume in print. The publisher's website hosts audio recordings of Wilson's poetry, which occupies two of the book's five chapters: <http://www.bucknell.edu/universitypress/alexanderwilson>.

Alexander Wilson developed an early passion for both nature and poetry, starting with his boyhood experiences as a cowherd. Later, as an apprentice weaver, his poetry took a turn toward activism on behalf of oppressed labour, which resulted in his being jailed under dubious circumstances. The story is outlined in a preliminary Biographical Sketch and further in the first chapter, which examines Wilson's life in Scotland through his poetry. Faced with continuing legal woes, Wilson emigrated to America in 1794, at the age of 28. There, he came under the mentorship and influence of William Bartram and Charles Wilson Peale, artists and naturalists both. Bartram was a mentor throughout Wilson's life in America, and Wilson supplied Peale with specimens for his museum, the country's first public natural history museum. After a brief stint as a school-teacher, Wilson decided to dedicate his life and "considerable artistic talent" to documenting the birds of America, travelling extensively for years over a region described as the "eastern deciduous forest". It was his constant practice to go beyond studying and describing the birds themselves, for he was endlessly curious about their behaviour and habitats wherever he went.

Wilson documented avian life through his paintings and field notes but recorded his travels through his poetry. The latter is the focus of chapter two, "Verses from America", the longest and least satisfying in the book. Wilson had much to say about nature and his experiences as a traveller, but I found the discussion here to be repetitive, remaining on the surface and suffering occasional errors of fact. Almost 30 pages are given to discussion of Wilson's "The Foresters", a poem of over 2000 lines describing a trip taken in 1804 with several

companions through Pennsylvania to Niagara Falls. The poet has much to say about the natural world around him and the conditions of the various people he and his companions met. Furthermore, Wilson's interest in painting birds was born during this trip, quickly blossoming into the concept of an American ornithology. Wilson wrote five poems on specific species of birds that are reprinted and discussed in the final section of this chapter.

As suggested above, the sections of most interest and relevance to field-naturalists are the final three chapters. Wilson's painting is analyzed in chapter three, "The Art of Illustrating Nature", by William E. Davis, Jr., who co-authored with Burt the 2013 biography of Wilson.¹ In the days before (and, thankfully, after) the invention of photography, painting and sketching were the primary methods available for visually recording natural phenomena. Techniques and talents varied, as well as principles, among the many who took up these methods. Davis compares Wilson's achievements with other notable painters, including Bartram, Catesby, Albin, and Edwards. For this discussion, more than 30 full colour plates are reproduced here, selected from a first edition of *American Ornithology* and collections in Harvard University's Ernst Mayr Library of Comparative Zoology. A professor of ornithology with a keen interest and skills in art, Davis is well placed to point out elements that escape the amateur's eye, guiding the reader into a fuller appreciation of the work. Sheer beauty aside, the accuracy Wilson achieved is a singularly important feature of his work, which was acknowledged in Europe – by Baron Cuvier, no less – for its high quality. Wilson completed eight volumes and had the ninth well underway at the time of his death in 1813. The full set, originally published between 1805–1814, was revised and republished under the direction of Prince Charles Lucian Bonaparte, estranged nephew of the dictator, up to 1877, the "first scientific work published in the fledgling United States" (p. 101).

Wilson took an innovative field guide approach, his work becoming steadily more ecologically, behaviourally, and morphologically accurate in line with his goal to produce paintings that would assist in bird identification in the field. He varied perspectives of his subjects when necessary, to highlight particular features and, unlike other painters, made sure to place his birds in appropriate habitats. Davis notes that Wilson paid special attention to the accurate depiction of eyes, feet, beaks and other features.

Chapter 4, "*American Ornithology: Exemplar of Scientific Creativity*", was written by Burt himself, who undertook a deep and fascinating textual analysis of Wilson's life work, placing it in the historical contexts of several themes. These themes include taxonomy, ecology, species, field notes and observation, use

¹C. Stuart Houston reviewed this biography in the CFN: **Houston, C. S.** 2013. [Book Review] Alexander Wilson, the Scot who Founded American Ornithology. *Canadian Field-Naturalist* 127: 283–284. <https://doi.org/10.22621/cfn.v127i3.1477>

of hypotheses, the art of publishing art, quantitative and economic ornithology, and the role of birds in culture. The concept of *aperçus* as the revisionist exploration of “[r]elations among historiography, culture and textual representation [that] are presently complex and rich in possibilities...” (p. [ii]) reaches full flight here. Burt digs deeply into the texts and the times, discussing problems with Linnaean taxonomy and its “chaotic naming” practices (p. 110), the limitations created by the notion of the fixity of individually divinely-created species and the lack of the taxonomic category of family, soon to be developed by Bonaparte.

A normal part of the practice of field research, one that photography eventually nullified, was the shooting of birds as specimens that could be prepared and kept for close study. While Wilson’s technique for preparation is described here, of much more interest is his practice of living with birds, captured or raised from eggs, at times for several years, so that he could study not only their form and colour, but their behaviours as well. As we have seen, Davis discussed how Wilson was the first to make honest application of these careful observations; here, Burt provides the how. Wilson’s close proximity to live animals. Wilson was the first in America to adopt the Linnaean system and his work became the foundation for both the first field guide to the birds of North America and the American Ornithological Union checklist, first published in 1883. He was also a source of information and anecdote – but unfortunately not for illustrations – for the life histories of birds published by A.C. Bent (p. 111). Wilson also produced in 1811 the first-ever breeding bird survey, undertaken at William Bartram’s “botanic garden” while he was living at Bartram’s home (p. 124).

The works of other artists, including the famous Mark Catesby, could result in inaccuracies in identification that might persist for years; Catesby, for example, painted from memory after moving back to Europe. Wilson’s field experience – indoors and out! – provided a corrective in several instances described by Burt, including the proof that the bird believed by European ornithologists to be the female Baltimore Oriole was in fact the male Orchard Oriole and that Bobolinks and so-called Rice Buntings were two separate species. His accomplishments in this regard were based solidly on his stubborn ability to trust what he saw rather than others’ descriptions, and to think for himself, testing hypotheses based on observation – something, according to Burt, “that no one else was doing” (p. 117). This statement extended as well to Wilson’s unique practice of keeping voucher specimens, some of which are now stored at the Ernst Mayer Library.

The issue of species identification is the subject of the short, concluding fifth chapter, “Bird Species: Then and Now”, by Frank Gill and Rick Wright, respectively an award-winning ornithologist (including an honorary

doctorate conferred at the symposium) and a scholar in the humanities who happens to write bird field guides. They briefly assess the state of knowledge in Wilson’s time in comparison to the extensive resources employed today. A great number of the birds Wilson observed were new to him and many were new to science. Wilson intended his work to be a guide to the species and, in addition to his extensive notes from the field, often made directly on life sketches, he collected physical specimens of male and female in their seasonal and breeding plumages. His close examination of these specimens resulted, as noted above, in clarification of several species. They expand on the discussion by Burt and offer other examples as well.

The limitations under which Wilson worked were not only physical. The philosophical questions he faced may seem almost quaint today, but our tremendous technologies, such as DNA analysis, force continuing evaluation of these questions at levels Wilson could not foresee. What he did foresee, however, was the continuing discovery of new species. He described and painted some 268 or 77% of the 348 known species in his lifetime. Yet today’s pioneers, bringing new specimens into the realm of the molecular, are uncovering new species even among long-described groups and species complexes. Thus, Gill and Wright inform us, the 14 described species of wren-babblers have recently been divided into “three unrelated families and include five new species, with more likely to come” (p. 154). Think you know your birds? Hang onto your binoculars – you’re in for a wild ride. Wilson would no doubt be pleased.

This book reflects the varied topics that arise in symposia covering a person’s life and work and diligently pursues their precise documentation. It is a book written by and with scholars in mind. However, much may be gleaned by those with an interest in the history of ornithology, the development of field practices, taxonomic issues, and the intersection of these with the arts of poetry and painting. The sections on poetry provided interesting insights into Wilson’s formative years and early life in America. However, I found the three chapters assessing his influential opus as a painter, his diligent practices as a field ornithologist – in contrast to those of Audubon, it may be said – and the problems of early taxonomy and speciation particularly fascinating. Wilson is more than worthy of the attention he receives here. In Burt’s words, Wilson “was a father who also gave his infant science the intellectual tools and rigor that would help it grow into a healthy, vibrant adult” (p. 107). And every painter of birds and student of ornithology ever since, knowing or not, is standing on his shoulders.

BARRY COTTAM
Ottawa, ON, Canada

NEW TITLES

Prepared by Barry Cottam

†Available for review *Assigned

Currency Codes – CAD Canadian Dollars, USD US Dollars, EUR Euros, AUD Australian Dollars, GBP British Pound.

BOTANY

A Handbook of the World's Conifers (2 vols.), Revised Edition. By Aljos Farjon. 2017. Brill. 1112 pages, 250.00 EUR, 300.00 USD, Cloth.

Trees: A Complete Guide to Their Biology and Structure. By Roland Ennos. 2016. Cornell University Press. 128 pages, 19.95 USD, Paper.

Fortress Plant: How to Survive When Everything Wants to Eat You. By Dale Walters. 2017. Oxford University Press. 320 pages, 29.95 USD, Cloth. Also available as an E-book.

Flora of Florida, Volume IV: Dicotyledons, Combretaceae through Amaranthaceae. By Richard P. Wunderlin, Bruce F. Hansen, and Alan R. Franck. 2017. University Press of Florida. 400 pages, 69.95 USD, Cloth.

How the Earth Turned Green: A Brief 3.8-Billion-Year History of Plants. 2014/2015. By Joseph E. Armstrong. University of Chicago Press. 576 pages, 137.00 USD, Cloth, 45.00 USD, Paper, 10.00–45.00 USD, E-book.

Seeds: A Natural History. By Carolyn Fry. 2016. University of Chicago Press. 192 pages and 186 colour plates, 35.00 USD, Cloth, 21.00 USD, E-book.

Wonders of the Plant Kingdom: A Microcosm Revealed. By Wolfgang Stuppy, Rob Kessler, and Madeline Harley. 2015. University of Chicago Press. 160 pages and 250 colour plates, 25.00 USD, Paper, 18.00 USD, E-book.

Plant Ecology: Origins, Processes, Consequences, Second Edition. By Paul A. Keddy. 2017. Cambridge University Press. 624 pages, 74.95 CAD, Cloth, 52.00 USD, E-book.

Plant Evolution: An Introduction to the History of Life. By Karl J. Niklas. 2016. University of Chicago Press. 560 pages, 45.00 USD, Paper or E-book.

Plant Sensing and Communication. Interspecific Interactions Series. By Richard Karban. 2015. University of Chicago Press. 240 pages, 114.00 USD, Cloth, 35.00 USD, Paper, 10.00–35.00 USD, E-book.

Hidden Natural Histories: Herbs. By Kim Hurst. 2015. University of Chicago Press. 224 pages and 150 colour plates, 25.00 USD, Paper, 18.00 USD, E-book.

Mosses, Liverworts, and Hornworts: A Field Guide to Common Bryophytes of the Northeast. By Ralph Pope. 2016. Cornell University Press. 384 pages and 2100+ illustrations, photographs, maps, and drawings, 24.95 USD, Paper.

The Book of Orchids: A Life-Size Guide to Six Hundred Species from around the World. 2017. By Mark Chase, Maarten Christenhusz, and Tom Mirenda. University of Chicago Press. 656 pages and 2400 colour plates, 55.00 USD, Cloth, 33.00 USD, E-book.

Wildflowers of the Maritimes. By Edmund Redfield. 2016. Nimbus Publishing. 216 pages, 24.95 CAD, Paper.

ENTOMOLOGY

Dr. Eleanor's Book of Common Ants. By Eleanor Spicer Rice, Alex Wild, and Rob Dunn. 2017. University of Chicago Press. 96 pages and 96 colour plates, 18.00 USD, Paper or E-book.

Dr. Eleanor's Book of Common Spiders. By Christopher M. Buddle and Eleanor Spicer Rice. 2017. University of Chicago Press. 80 pages and 72 colour plates, 20.00 USD, Paper, 18.00 USD, E-book.

Bee Time: Lessons from the Hive. By Mark L. Winston. 2016. Harvard University Press. 296 pages, 24.95 USD, Cloth, 18.95 USD, Paper.

Following the Wild Bees: The Craft and Science of Bee Hunting. By Thomas D. Seeley. 2016. Princeton University Press. 184 pages, 22.95 USD, Cloth. Also available as an E-book.

Solitary Bees. Naturalist Handbooks 33. By Ted Benton. 2017. Pelagic Publishing. 208 pages, 33.71 CAD, Paper.

The Dancing Bees: Karl von Frisch and the Discovery of the Honeybee Language. By Tania Munz. 2016. University of Chicago Press. 296 pages, 30.00 USD, Cloth.

A Natural History of Ladybird Beetles. By M.E.N. Majerus. 2017. Cambridge University Press. 403 pages, 68.95 CAD, Cloth, 53.15 CAD, E-book.

Infested: How the Bed Bug Infiltrated Our Bedrooms and Took Over the World. By Brooke Borel. 2015. University of Chicago Press. 224 pages, 26.00 USD, Cloth, 16.00 USD, Paper or E-book.

Fireflies, Glow-worms, and Lightning Bugs: Identification and Natural History of the Fireflies of the Eastern and Central United States and Canada. By Lynn Frierson Faust. 2017. University of Georgia Press. 376 pages, 32.95 USD, Paper.

Monarchs and Milkweed: A Migrating Butterfly, a Poisonous Plant, and Their Remarkable Story of Coevolution. By Anurag Agrawal. 2017. Princeton University Press. 296 pages, 29.95 USD, Cloth. Also available as an E-book.

Identification and Geographical Distribution of the Mosquitoes of North America, North of Mexico. By Richard F. Darsie Jr. and Ronald A. Ward. 2016. University Press of Florida. 398 pages, 45.00 USD, Paper.

Moth. By Matthew Gandy. 2016. Reaktion Books. 224 pages and 100 colour plates, 19.95 USD, Paper.

Insects: Evolutionary Success, Unrivaled Diversity, and World Domination. By David B. Rivers. 2017. Johns Hopkins University Press. 576 pages, 99.95 USD, Cloth or E-book.

Biological Control: Ecology and Applications. By George E. Heimpel and Nicholas J. Mills. 2017. Cambridge University Press. 386 pages, 68.95 CAD, Cloth, 64.52 CAD, E-book.

Eat the Beetles!: An Exploration into Our Conflicted Relationship with Insects. By David Waltner-Toews. 2017. ECW Press. 276 pages, 19.95 CAD, Paper.

ZOOLOGY

Amphibians and Reptiles of the Great Lakes Region, Revised Edition. By James H. Harding and David A. Mifsud. 2017. University of Michigan Press. 408 pages, 60.00 USD, Cloth, 24.95 USD, Paper or E-book.

The Snake and the Salamander: Reptiles and Amphibians from Maine to Virginia. By Alvin R. Breisch. Illustrations by Matt Patterson. 2017. Johns Hopkins University Press. 232 pages, 49.95 USD, Cloth or E-book.

Snakes of the Eastern United States. Wormsloe Foundation Nature Book. By Whit Gibbons. 2017. University of Georgia Press. 392 pages, 32.95 USD, Paper.

***Turtles as Hopeful Monsters: Origins and Evolution.** Life of the Past Series. By Olivier Rieppel. 2017. Indiana University Press. 216 pages, 45.00 USD, Cloth or E-book.

Beaked Whales: A Complete Guide to Their Biology and Conservation. By Richard Ellis and James G. Mead. 2017. Johns Hopkins University Press. 208 pages, 79.95 USD, Cloth or E-book.

The Arctic Guide: Wildlife of the Far North. By Sharon Chester. 2016. Princeton University Press. 544 pages, 27.95 USD, Paper. Also available as an E-book.

Marine Plankton: A Practical Guide to Ecology, Methodology, and Taxonomy. Edited by Claudia Castellani and Martin Edwards. 2017. Oxford University Press. 704 pages, 225.00 USD, Cloth. Also available as an E-book.

The Marine World: A Natural History of Ocean Life. By Frances Dipper. 2017. Cornell University Press. 544 pages and 3500 illustrations, photographs, drawings, and charts, 59.95 USD, Cloth.

Transforming the Fisheries: Neoliberalism, Nature, and the Commons. By Patrick Bresnihan. 2016. University of Nebraska Press. 240 pages, 45.00 USD, Cloth.

Beautifully Grotesque Fish of the American West. By Mark Spitzer. 2017. University of Nebraska Press. 232 pages, 24.95 USD, Cloth.

Cheats and Deceits: How Animals and Plants Exploit and Mislead. By Martin Stevens. 2016. Oxford University Press. 296 pages, 34.95 USD, Cloth. Also available as an E-book.

The Seabird's Cry: The Lives and Loves of Puffins, Gannets and Other Ocean Voyagers. By Adam Nicolson. Illustrations by Kate Boxer. 2017. William Collins (Harper Collins imprint). 228 pages, 34.99 CAD, Cloth.

The Peregrine Returns: The Art and Architecture of an Urban Raptor Recovery. By Mary Hennen with Peggy Macnamara. Illustrations by Peggy Macnamara

and photographs by Stephanie Ware. 2017. University of Chicago Press. 208 pages, 25.00 USD, Cloth, 18.00 USD, E-book.

***Raptors: The Curious Nature of Diurnal Birds of Prey.** By Keith L. Bildstein. 2017. Cornell University Press. 336 pages, 35.00 USD, Cloth.

Raptor: A Journey through Birds. By James Macdonald Lockhart. 2017. University of Chicago Press. 384 pages, 29.00 USD, Cloth, 18.00 USD, E-book.

Snowbird: Integrative Biology and Evolutionary Diversity in the Junco. Edited by Ellen D. Ketterson and Jonathan W. Atwell. 2015. University of Chicago Press. 416 pages, 60.00 USD, Cloth, 10.00–60.00 USD, E-book.

Why Birds Matter: Avian Ecological Function and Ecosystem Services. Edited by Çagan H. Sekercioglu, Daniel G. Wenny, and Christopher J. Whelan. 2016. University of Chicago Press. 368 pages, 135.00 USD, Cloth, 45.00 USD, Paper or E-book.

Birds: A Complete Guide to Their Biology and Behaviour. By Jonathan Elphick. 2016. Firefly Books/London Natural History Museum. 272 pages, 29.95 CAD, Paper.

Bird Brain: An Exploration of Avian Intelligence. By Nathan Emery. Foreword by Frans de Waal. 2016. Princeton University Press. 192 pages, 29.95 USD, Cloth or E-book.

The Sensory Ecology of Birds. Oxford Avian Biology Series. By Graham R. Martin. 2017. Oxford University Press. 320 pages, 95.00 USD, Cloth.

Nests, Eggs, & Incubation: New Ideas About Avian Reproduction. Edited by D. Charles Deeming and S. James Reynolds. Foreword by Tim R. Birkhead. 2015/2016. Oxford University Press. 320 pages, 136.50 CAD, Cloth, 73.50 CAD, Paper. Also available through Oxford Scholarship Online.

The Most Perfect Thing: Inside (and Outside) a Bird's Egg. By Tim Birkhead. 2016. Bloomsbury Publishing. 304 pages, 27.00 USD, Cloth, 17.99 USD, E-book.

Is Birdsong Music? Outback Encounters with an Australian Songbird. By Hollis Taylor. 2017. Indiana University Press. 364 pages, 80.00 USD Cloth, 39.00 USD, Paper or E-book.

***Flock Together: A Love Affair with Extinct Birds.** By B.J. Hollars. 2017. University of Nebraska Press. 224 pages, 24.95 USD, Cloth.

How to Tame a Fox (and Build a Dog): Visionary Scientists and a Siberian Tale of Jump-Started Evolution. By Lee Alan Dugatkin and Lyudmila Trut. 2017. University of Chicago Press. 240 pages, 26.00 USD, Cloth, 18.00 USD, E-book.

Mammals of the Great Lakes Region, Third Edition. By Allen Kurta. 2017. University of Michigan Press. 416 pages, 60.00 USD, Cloth, 24.95 USD, Paper.

How the Zebra Got Its Stripes: Darwinian Stories Told Through Evolutionary Biology. By Léo Grasset. Translated by Barbara Mellor. 2017. Penguin Random House Canada – Pegasus Books. 160 pages, 35.95 CAD, Cloth.

Zebra Stripes. By Tim Caro. 2016. University of Chicago Press. 320 pages, 45.00 USD, Cloth or E-book.

The Skeleton Revealed: An Illustrated Tour of the Vertebrates. By Steve Huskey. 2017. Johns Hopkins University Press. 360 pages, 49.95 USD, Cloth or E-book.

OTHER

***Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming.** Edited by Paul Hawken. 2017. Penguin Books. 240 pages, 29.00 CAD, Paper.

About Method: Experimenters, Snake Venom, and the History of Writing Scientifically. By Jutta Schickore. 2017. University of Chicago Press. 320 pages, 50.00 USD, Cloth or E-book.

Curators: Behind the Scenes of Natural History Museums. By Lance Grande. 2017. University of Chicago Press. 432 pages and 146 colour plates, 35.00 USD, Cloth, 21.50 USD, E-book.

Science in the Archives: Pasts, Presents, Futures. Edited by Lorraine Daston. 2017. University of Chicago Press. 392 pages, 112.50 USD, Cloth, 37.50 USD, Paper or E-book.

Collecting Evolution: The Galapagos Expedition that Vindicated Darwin. By Matthew J. James. 2017. Oxford University Press. 304 pages, 34.95 USD, Cloth. Also available as an E-book.

Improbable Destinies: Fate, Chance, and the Future of Evolution. By Jonathan B. Losos. 2017. Riverhead Books. 384 pages, 28.00 USD, Cloth.

Great Transformations in Vertebrate Evolution. Edited by Kenneth P. Dial, Neil Shubin, and Elizabeth L. Brainerd. 2015. University of Chicago Press. 424 pages, 45.00 USD, Paper, 36.00–45.00 USD, E-book.

Evolutionary Theory: A Hierarchical Perspective. 2016. Edited by Niles Eldredge, Telmo Pievani, Emanuele Serrelli, and Ilya Temkin. University of Chicago Press. 384 pages, 105.00 USD, Cloth, 35.00 USD, Paper or E-book.

Coevolution of Life on Hosts: Integrating Ecology and History. By Dale H. Clayton, Sarah E. Bush, and Kevin P. Johnson. 2015. University of Chicago Press. 320 pages, 120.00 USD, Cloth, 45.00 USD, Paper, 10.00–45.00 USD, E-book.

The Origin of Higher Taxa: Palaeobiological, Developmental, and Ecological Perspectives. By T. S. Kemp. 2015. University of Chicago Press. 320 pages, 120.00 USD, Cloth, 49.00 USD, Paper, 10.00–49.00 USD, E-book.

Patterns in Nature: The Analysis of Species Co-Occurrences. By James G. Sanderson and Stuart L. Pimm. 2015. University of Chicago Press. 184 pages, 45.00 USD, Cloth, 10.00–45.00 USD, E-book.

Messages from Islands: A Global Biodiversity Tour. By Ilkka Hanski. 2016. University of Chicago Press. 272 pages, 100.00 USD, Cloth, 32.50 USD, Paper, 32.50 USD, E-book.

Life in the Dark: Illuminating Biodiversity in the Shadowy Haunts of Planet Earth. By Danté Fenolio. 2016. Johns Hopkins University Press. 312 pages and 446 colour photos, 39.95 USD, Cloth or E-book.

Untamed Atlantic Canada: Exploring the Region's Biodiversity Havens. By Scott Leslie. 2016. Nimbus Publishing. 200 pages, 27.95 CAD, Paper.

Dead Zone: Where the Wild Things Were. By Philip Lymbery. 2017. Bloomsbury Natural History. 384 pages, 10.99 USD, E-book.

Furry Logic: The Physics of Animal Life. By Matin Durrani and Liz Kalaugher. 2017. Bloomsbury Natural History. 304 pages, 27.00 USD, Cloth.

Science, Conservation, and National Parks. Edited by Steven R. Beissinger, David D. Ackerly, Holly Doremus, and Gary E. Machlis. 2016. University of Chicago Press. 416 pages, 130.00 USD, Cloth, 45.00 USD, Paper or E-book.

Pollination Power. By Heather Angel. 2016. University of Chicago Press. 208 pages and 204 colour plates, 40.00 USD, Cloth.

‡ **The Eye of the Sandpiper: Stories from the Living World.** By Brandon Keim. 2017. Cornell University Press. 240 pages, 19.95 USD, Paper.

Wildness: Relations of People and Place. Edited by Gavin Van Horn and John Hausdoerffer. 2017. University of Chicago Press. 272 pages, 90.00 USD, Cloth, 30.00 USD, Paper or E-book.

‡ **Mourning Nature: Hope at the Heart of Ecological Loss and Grief.** Edited by Ashlee Cunsolo and Karen Landman. 2017. McGill-Queen's University Press. 360 pages, 110.00 CAD, Cloth, 37.95 CAD, Paper.

Tense Bees and Shell-Shocked Crabs: Are Animals Conscious? By Michael Tye. 2016. Oxford University Press. 256 pages, 32.95 CAD, Cloth.

The Species Problem: A Philosophical Analysis. Cambridge Studies in Philosophy and Biology. 2015. By Richard A. Richards. Cambridge University Press. 248 pages, 38.95 CAD, Paper. Cloth and E-book formats published in 2010.

***This River Beneath the Sky: A Year on the Platte.** By Doreen Pfof. 2016. University of Nebraska Press – Bison Books. 198 pages, 18.95 USD, Paper.

The River. By Helen Humphreys. 2016. ECW Press. 216 pages, 24.95 CAD, Paper.

Returning North with the Spring. By John R. Harris. 2016. University Press of Florida. 232 pages, 24.95 USD, Cloth.

Through a Naturalist's Eyes: Exploring the Nature of New England. By Michael J. Caduto. Illustrations by Adelaide Murphy Tyrol. 2016. University Press of New England. 240 pages, 19.95 USD, Paper, 14.99 USD, E-book.

Common Ground: Encounters with Nature at the Edges of Life. By Rob Cowen. 2016. University of Chicago Press. 352 pages, 29.00 USD, Cloth, 18.00 USD, E-book.

Call of Nature: The Secret Life of Dung. By Richard Jones. 2017. Pelagic Publishing. 303 pages, 28.65 CAD, Cloth or E-book.

RSPB Gardening for Wildlife. By Adrian Thomas. 2017. Bloomsbury Natural History. 288 pages, 40.00 USD, Cloth.

News and Comment

Upcoming Meetings and Workshops

American Ornithology 2017

American Ornithology 2017, the inaugural meeting of the American Ornithological Society and the Society of Canadian Ornithologists/Société des ornithologistes du Canada to be held 31 July–5 August 2017 at the Kellogg Hotel and Conference Center, Michigan State University, East Lansing, Michigan. The theme of the conference is: 'Birds in the Anthropocene'. Registration is currently open. More information is available at <http://aossco2017.fw.msu.edu>.

Ecological Society of America Annual Meeting

The annual meeting of the Ecological Society of America to be held 6–9 August 2017 at the Oregon Convention Center, Portland, Oregon. The theme of the conference is: 'Linking Biodiversity, Material Cycling and Ecosystem Services in a Changing World'. Registration is currently open. More information is available at <http://www.esa.org/portland/#.WF06uVMrLIU>.

Northeast Partners in Amphibian and Reptile Conservation Annual Meeting

The Northeast Partners in Amphibian and Reptile Conservation Annual Meeting to be held 8–10 August 2017 at the Mountain Lake Biological Station, Pembroke, Virginia. Registration is currently open. More information is available at <http://northeastparc.org/next-meeting-info>.

American Fisheries Association Meeting

The 147th annual meeting of the American Fisheries Association to be held 20–24 August 2017 at the Tampa Convention Center, Tampa, Florida. The theme of the conference is: 'Fisheries Ecosystems: Uplands to Oceans'. Registration is currently open. More information is available at <https://afs-annualmeeting.fisheries.org>.

51st North American Moose Conference/Workshop

The 51st North American Moose Conference/Workshop to be held 28 August–1 September 2017 at the Keltic Lodge, Ingonish, Cape Breton, Nova Scotia. The theme of the conference is: 'Hyper-Abundant Moose Populations – Ecological Consequences and Management Strategies'. Registration is currently open. More information is available at <http://alcesjournal.org/index.php/alces/announcement/view/20>.

Ontario's Environmental Review Tribunal overturns the Renewable Energy Approval for a second wind farm project on the grounds of serious and irreversible harm to wildlife

On 26 April 2017 Ontario's Environmental Review Tribunal issued a decision that substantially reduced the size of wpd White Pines Wind Incorporated's Prince Edwards County, Ontario wind farm project, on the grounds of serious and irreversible harm to wildlife. This is the second time that a Prince Edwards County wind farm project, approved under the *Ontario Green Energy Act* and *Environmental Protection Act*, has been overturned by the Tribunal because of its potential effects on at-risk species. In June 2016, the Tribunal revoked the Renewable Energy Approval for the Ostrander Point Wind Farm.

The wpd White Pines Wind Incorporated wind farm project was issued its Renewable Energy Approval by the Ontario Ministry of the Environment and Climate Change on 16 July 2015. As approved, this project would have involved the construction, installation, and operation of 27 turbines and two transformer stations, plus associated underground electrical cabling, distribution lines, and other infrastructure, including roads.

This project was opposed by John Hirsch and the Alliance to Protect Prince Edward County, who filed a notice of appeal with the Environmental Review Tribunal. They argued that the project's Renewable Energy Approval should be revoked on the grounds that it would cause serious and irreversible harm to plant and animal life, the natural environment, and human health. In particular, the Tribunal proceedings focused on the potential harm to the Little Brown Bat (*Myotis lucifugus*) and Blanding's Turtle, and the actions proposed by wpd to mitigate those risks. Both of these species are federally listed as endangered, and are thus protected under the *Species at Risk Act*.

For the Little Brown Bat, the Tribunal found that it was possible for wpd to mitigate the main risk posed by the wind farm, i.e., the risk of mortality from the rotating turbines. To mitigate the risk of bat mortality, turbines will not operate under wind speeds of 5.5 m/s when the bats are most active, i.e., from sunrise to sunset each day, from 1 May – 30 September. The area around each wind turbine would also be monitored and if any bat fatalities were found further mitigation actions would be required.

For the Blanding's Turtle (*Emydoidea blandingii*), the Tribunal found that the proposed mitigation actions were not sufficient. The main risk to turtles considered by the Tribunal was the network of access roads needed for turbine installation and maintenance, specifically that the required modifications to the local road network would increase rates of adult turtle mortality and nest predation. The Tribunal accepted the mitigation actions to minimize nest predation, including relocation of roadside nests to a wildlife rehabilitation centre for incubation and caging nests to reduce predation. However, the Tribunal found that there was not enough evidence to support the implementation of wpd's proposed mitigation actions to reduce rates of adult turtle mortality. In response to the concerns that the wind farm project could increase rates of adult Blanding's Turtle mortality, the Tribunal decided to remove from the Renewable Energy Approval all the proposed turbines associated with the modified road network in Blanding's Turtle habitat. This resulted in the removal of 18 of the 27 proposed turbines from the project.

This is not the first time that a Renewable Energy Approval has been overturned on the grounds that the approved project would cause serious harm to the Blanding's Turtle: the Ostrander wind farm project was previously halted for very similar reasons (see *Canadian Field-Naturalist* 129: 182–183 and *Canadian Field-Naturalist* 130: 215). However, the difference is that the Ostrander wind farm project would have been built on crown land, while wpd's turbines would be on private property. This decision shows that the benefits of renewable energy generation do not take precedence over other environmental concerns, including wildlife protection, regardless of whether those projects occur on public or private lands.

For further information, see:

Environmental Review Tribunal. 2017. *Hirsch v. Ontario (Environment and Climate Change)*. Case No. 15-068. Accessed 3 May 2017. <http://www.ert.gov.on.ca/files/20170400000300-FCU397E-FE-X0026-HDQ508076Q0026.pdf>

Government of Canada. 2017. Species at Risk Public Registry. Accessed 21 May 2017. <http://www.registrelep-sara.registry.gc.ca/default.asp?lang=En&n=24F7211B-1>

Stantec Consulting Ltd. 2012. White pines wind project project description report. Stantec Consulting Ltd., Guelph, Ontario, Canada. Accessed 22 May 2017. http://canada.wpd.de/uploads/tx_projectdownloads/WPWF_2_PDR_20120901_Web.pdf

AMANDA E. MARTIN

Carleton University, Ottawa, ON, Canada

Remembering Leslie Cody

Leslie was always cheerful and positive. She was also very kind and had some remarkable skills which she applied happily to her father's (Bill Cody's) botanical research and to *The Canadian Field-Naturalist* (CFN), a science journal of field biology and ecology locally-published by the Ottawa Field-Naturalists' Club (OFNC). She typed and commented upon so many scientific manuscripts that it can be said she played a significant role in the dispersal of botanical information on Canada's north, where her father's research was focussed.

As part of the CFN production team, Leslie produced indices for 21 four-issue volumes (nos. 106–126, authored as Leslie Durocher and later Leslie Cody). These indices were often around 30 pages in length and were remarkably complete and accurate. She sometimes found mistakes and contacted authors so that spellings would be correct in the index. It was in 1992 that she took over the job of indexing from Harvey Beck, whose *modus operandi* was to compile index entries in a card file, merge and organize all entries once a volume was

complete, and then type the index. Leslie did all this with a computer, modernizing the production of the journal. Leslie also maintained the CFN mailing list and she took great pride in keeping it up-to-date. She played a key role in the achievements of the OFNC and she helped to advance the club's objectives, particularly that of diffusing the results of natural history research as widely as possible. Her contributions to the OFNC and particularly to CFN can be figured in the thousands of hours.

Leslie passed away on 31 January 2017 after a long battle with cancer. It is a pleasure to remember her cheerful disposition and her very substantial contributions while part of our team. She was a superhero and a close friend who carried a burden of seriously ill health very courageously and all of us thoroughly enjoyed working with her.

PAUL CATLING, FRANCIS COOK, JEFF SAARHA, WENDY COTTE,
FRANK POPE – OFNC PUBLICATIONS COMMITTEE

Minutes of the 138th Annual Business Meeting of the Ottawa Field-Naturalists' Club January 10, 2017

Place and time: Fletcher Wildlife Garden, Ottawa, Ontario, 7:00 pm
Chairperson: Henry Steger, Chair Membership Committee, OFNC

Over 20 attendees spent the first half-hour reviewing the minutes of the previous ABM, the financial statements and Treasurer's Report, the annual reports of OFNC committees for 2015–2016, and OFNC's submission to Ontario's EBR on the hunting of Snapping Turtles. The meeting was called to order at 7:30 pm.

1. Minutes of the Previous Annual Business Meeting

It was moved by Annie Bélair and seconded by Ian Whyte that the minutes of the 137th Annual Business Meeting be accepted as distributed and published in *The Canadian Field-Naturalist*.

Carried

2. Business Arising from the Minutes

Nil.

3. Communications Relating to the Annual Business Meeting

OFNC received a fine Christmas card from the Governor General of Canada, David Johnston.

4. Treasurer's Report by Ken Young

Ken presented the financial statements, which were reviewed by the accounting firm of Welch LLP. He said that assets peaked in the previous fiscal year, when the final disbursement from the Czasak estate to the Club was made. Club assets will probably decline over the coming years as we use our resources to further conservation of, and education about natural history.

The major sources of revenue for the Club are membership fees, donations and bequests, and subscription charges and authors' charges for *The Canadian Field-Naturalist*. Both membership and donations rose in FY2016 but *The Canadian Field-Naturalist* revenues are down. Revenues (and expenses) are up compared to 2015 because of the Pelee trip held in 2016.

Expenses rose during the year, primarily from projects made possible by the bequest of Violetta Czasak (item 8).

The Board of Directors approved the budget for the Club at its October 17 meeting. The budget is attached to the minutes of that meeting which are available on the OFNC website.

This year, the budget forecasts revenues of \$113,000, expenses of \$227,740, and a deficit of over \$114,000. The deficit is overstated, however, due to an assumption that the \$40,000 cost of rehabilitating the Fletcher

Wildlife Garden pond would occur this fiscal year. In fact, most of the work was completed in September 2016 and those expenses are included in FY2016. Still, the Board expects a significant deficit this year and for the foreseeable future.

Investments of the OFNC are made according to a policy established by the Board of Directors, and implemented by a Board appointee (last year it was Ann MacKenzie) and our investment advisor, Sue Anderson of BMO Nesbitt Burns.

As in the past, we have received excellent service from our accounting firm, Welch LLP, and our reviewer, Eric Liebmann, to whom I give thanks. We have contracted with a new bookkeeping firm and expect that will produce more efficient financial processes over time. He noted that combining one or two of the Club's smaller accounts into the General Fund would simplify the Treasurer's work with no loss in accountability.

Ken is retiring as Treasurer. In closing, he thanked Frank Pope, past treasurer, and Ann MacKenzie who will be taking over the Treasurer's duties, for their assistance.

Moved by Ken Young, seconded by Ann MacKenzie, that the financial statements be accepted as a fair representation of the financial position of the Club as of September 30, 2016.

Carried

5. Nomination of the Accounting Firm

Moved by Ken Young and seconded by Ian Whyte, that the accounting firm of Welch LLP be contracted to conduct a review of the OFNC's accounts for the fiscal year ending September 30, 2017.

Carried

6. Committee Reports

The annual committee reports tell the story of what the OFNC has done year by year.

Moved by Lynn Ovenden and seconded by Gord Robertson, that the committee reports be accepted as distributed.

Carried

7. Nominations for Board of Directors positions

Relevant Excerpts from the OFNC Constitution (revised February 2000)

Article 8 “The Council shall consist of the officers of the Club and up to eighteen additional members, all members of the Club.”

Article 12 “The officers of the Club and other members of the Council shall be elected annually at the Annual Business Meeting. The nomination of sufficient persons for election to the various offices and membership of the Council shall be the responsibility of the Nominating Committee, which shall act in the manner prescribed in the By-Laws.

The Council shall, at the earliest possible date, appoint chairs and members of Standing and ad hoc committees and Editor and Business Managers, as required for club publications.”

NOMINATED OFFICERS	OFFICIAL DUTY
Diane Lepage	President
Jakob Mueller	1 st Vice-President
Vacant	2 nd Vice-President
Lynn Ovenden	Recording Secretary
Ann MacKenzie	Treasurer

NOMINATED OTHER MEMBERS (in alphabetical order)	
Annie Bélair	Rémy Poulin
Fenya Brodo	Gordon Robertson
Owen Clarkin	Jeff Saarela
Edward Farnworth	Henry Steger
Diane Kitching	Eleanor Zurbrigg
Dwayne Lepitzki	

Moved by Ann MacKenzie and seconded by Annie Bélair that this slate of nominees be accepted as members of the Board of Directors of the OFNC for 2017.

Carried

Moved by Ken Young and seconded by David Hobden that: (i) Diane Lepage, President, and Ann MacKenzie, Treasurer, have signing authority for OFNC banking with the Canadian Imperial Bank of Commerce (CIBC), and that (ii) one signature by either person with signing authority is sufficient to authorize payment and write cheques.

Carried

Henry expressed everyone’s gratitude to Fenja Brodo for her leadership as President for the past three years; she will continue to serve as Past President. He thanked Ken Young and Barry Cottam who are leaving the Board of Directors. Ken served as Chair of the Conservation Committee and recently as Treasurer. Barry was Club representative to Ontario Nature. He is now the Book Editor for *The Canadian Field-Naturalist*. Henry recognized Alex MacDonald’s positive contribution as liaison between Nature Canada and OFNC;

he has left the Board of Directors for a new position in Halifax. Finally, Henry welcomed Ann Mackenzie (Treasurer), Diane Lepage (President) and Jakob Mueller (1st Vice President) to their new roles.

Committee chairs will be approved by the Board of Directors at the January 2017 meeting.

8. Bequest of Violetta Czasak

Ann MacKenzie gave a brief presentation on how the Board has handled the bequest from Violetta Czasak. Ann thanked Ken Young for acting as the Executor for the estate which was an enormous amount of work. Funds were released to the Club starting in 2013 with the final payment in 2016 for a total of over \$1.0 million.

The Board established an Ad Hoc Bequest Committee to give them guidance but it was not designed as an approval committee. They recommended that the funds be spread among the several activities of the Club and have a long term impact. They proposed a possible breakdown of the funds between land acquisition (\$400k), Club operations (\$250k), grants to others (\$250k), and a speaker’s series (\$100k).

To date the Club has spent or committed about half the funds. We supported the Nature Conservancy’s acquisition of the Gervais property in Westmeath and contributed to the Lost Bay Reserve of Ontario Nature. Less than \$100k has gone toward Club operations such as the member survey, fixing up the Fletcher Wildlife Garden centre, and increasing honorariums. Support for projects of sister organizations has amounted to about \$25k although it was not included in the original suggestions. Grants to others has been an exciting area. Our program of research grants (\$15k per year) is proving popular and encouraging projects as well as articles for *Trail & Landscape*. Annual financial support (\$5k) to the Ottawa School Board Outdoor Centres is just beginning and should help increase access to the natural world by students in financially challenged schools.

The bequest is a tremendous assistance to the OFNC in working towards its objectives.

9. Snapping Turtle Harvest

On behalf of OFNC, Dave Seburn and the Conservation Committee prepared detailed comments on Ontario’s proposal to restrict the hunting of Snapping Turtles. His submission explains why any hunt for this long-lived species is unsustainable and requests that the hunt be ended rather than restricted. Attendees were encouraged to submit their own comments to Ontario on the Environmental Registry (EBR Registry No. 012-9170).

10. Edward Lloyd Bousfield, Honorary Member

The OFNC noted with sadness the passing of Edward Lloyd Bousfield who joined the OFNC in 1951. During a long career in Ottawa’s Museum of Nature,

the Royal Ontario Museum, and the Royal BC Museum in Victoria, he described hundreds of marine amphipod species.

11. New Business and General Discussion

- a) Dan Brunton said the Publications Committee is considering ideas for a publication celebrating the significant field naturalists in Canada over the past few hundred years.
- b) Diane Lepage invites Club members and other subject experts to lead walks and workshops as part of a Bioblitz in Gatineau Park planned for June 10–11.
- c) Annie Bélair presented gifts of appreciation to Barry Cottam (proof-reader) and Diane Kitching (copy editor) for their assistance on recent issues of *Trail & Landscape*.

- d) Ian Whyte conveyed many members' wish to somehow restore Bruce DiLabio's weekly birding column which is no longer published by the *Ottawa Citizen*.

Moved by Ian Whyte and seconded by Barry Cottam, that the Board favourably consider inviting Bruce DiLabio to publish a weekly birding article on OFNC's website.

Carried

12. Adjournment

Moved by Diane Lepage and seconded by David Hobden that the meeting be adjourned.

Carried

LYNN OVENDEN
Recording Secretary

Annual Report of the Ottawa Field Naturalist Club: October 2015 – September 2016

Awards Committee

The Awards Committee manages the process to annually recognize those OFNC members and other qualified persons who, by virtue of their efforts and talents, are deserving of special recognition. In 2016, nominations were received and evaluated (see awards criteria at <http://www.ofnc.ca/awards.php>), resulting in nominees for four awards being recommended to the Board of Directors for approval. Biographies were written for each award winner for publication in the Club's journals and posting on the website. The awards were presented at the annual Awards Night in April. The recipients' names, type of award (in brackets), and rationale for recognition follow below.

- Robert E. Lee (Honorary Member) In recognition of lifetime contributions to natural history teaching and investigation and dedicated leadership of the Macoun Field Club.
- Lynn Ovenden (Member of the Year) For delivering a communications plan for the Club and initiating website modernization.
- Roy John (George McGee Service) For 12 years of service as the Book Review Editor for *The Canadian Field-Naturalist*, leading Pelee trips and bird walks.
- Miller Paving Limited (Conservation – Non-member) – For land conservation at the Braeside Quarry.

Committee members: Irwin Brodo, Julia Cipriani, Christine Hanrahan, Karen McLachlan Hamilton

ELEANOR ZURBRIGG, Chair

Birds Committee

The Birds Committee and the Club des Ornithologues de l'Outaouais held another popular Christmas Bird Count in 2015. The Peregrine Falcon Watch has been put on hold while we wait for a successful nest at the downtown site. The second nest site at Heron Road is being informally watched as it was deemed to be a safe nesting location without the need for constant monitoring. Safe Wings Ottawa (formerly a chapter of Fatal Light Awareness) continues to build its program and raise awareness of the dangers of glass for bird collisions. The committee continues to maintain a number of bird feeders in the Ottawa region and this past winter started to fund the feeder at the Natural Heritage Campus of the Museum of Nature in Gatineau, Quebec.

CHRIS TRAYNOR, Chair

Conservation Committee

Highlights for 2016 include:

Letter-writing:

1. American Eel:

In February, the committee put out a call for conservation action for the American Eel (*Anguilla rostrata*; <https://ofnc.wordpress.com>) and in April submitted a letter to Fisheries and Oceans Canada.

2. Habitat loss for sensitive species Kanata:

In February, the committee raised awareness regarding anticipated impacts on sensitive species (e.g., Blanding's Turtle [*Emydoidea blandingii*] of Kanata Lakes North Development Inc.'s proposed development (<https://ofnc.wordpress.com>)).

3. Turtle Recovery Management (May):

Spearheaded by the expertise of Dave Schurn, the committee drafted letters reviewing the draft Recovery Planning program of Environment and Climate Change Canada, for the following three species: 1. Blanding's Turtle (recovery plan), 2. Spotted Turtle (recovery plan), and 3. Snapping Turtle (management plan).

4. Review of the Navigation Protection Act:

In November, the committee submitted a letter to The Standing Committee on Transport, Infrastructure and Communities regarding the *Navigation Protection Act*. Briefly, the committee encouraged the federal government to restore lost protections and incorporate modern safeguards to the act, pointing to the historical *Navigable Waters Protection Act*.

"How-to" Articles:

1. "Brush piles: improving backyard habitat" (Fred Schueler), February 2016
<https://ofnc.wordpress.com>
2. "Build a "home" for mason bees" (Sandy Garland), May 2016
<https://ofnc.wordpress.com>
3. "The importance of snags and downed logs to wildlife" (Christine Hanrahan), July 2016
<https://ofnc.wordpress.com>

Upcoming articles are in development regarding topics including: a Wild Parsnip Position Paper regarding recent herbicide programs, How and Why to cultivate indigenous woody plants, and Ponds-how-to: Reintroducing ponds and their associated wildlife to the human environment.

Lecture to OFNC membership:

1. "Twigs: Introduction to the Fingerprint of Woody Plants" (Owen Clarkin), April 2016
<https://www.facebook.com>
Inspired partially by a mini-lecture given at the 3rd Annual OFNC Members Photo Night in January
<https://ofnc.wordpress.com>

Other Activities:

1. Mostly as individuals in their respective fields of expertise: several members continue to be active as volunteers tour leaders, lecturers, bioblitzers, and reviewers of conservation related projects proposals for OFNC and other organizations.
2. The committee continues to collaborate with the OFNC Events committee to help plan conservation-themed events for the club.
3. Erwin Dreessen left OFNC-conservation as Greenspace Alliance representative; position has been filled by Paul Johannis.
4. Social Media as a Conservation Tool (iNaturalist Facebook Groups), emphasis on plants to date. Continued advocacy and leadership on social media plant identification forums, from the perspective of accurate species identification as being a foundational key to conservation. A community service to help others, but also citizen-science tool to gather statistics of rapidly changing

plant populations: e.g., natives/non-natives/invasives from local and worldwide perspectives.

a. Demonstrated iNaturalist as a bioinventory database tool at "Engaging Citizens in Science" event hosted by the city of Ottawa in April.

b. The chair, as an individual, actively co-administers and regularly contributes IDs to two prominent international (largest of their kind) and one local group:

"Plant Identification" (83000+ members)

<https://www.facebook.com/>

"Tree Identification" (6900+ members)

<https://www.facebook.com/>

"Tree Ottawa Tree ID and Tree Discussion" (380+ members)

<https://www.facebook.com/>

5. The committee did not request or use club funds in 2016.

OWEN CLARKIN, Chair

Education and Publicity Committee

It was a busy year. First Gordon Robertson took the chair after Lynn Ovenden stepped down to become Secretary of the OFNC Board. This year we lost a few members but one new member, Joel Buffam has recently joined the committee. There were approximately a dozen presentations or nature tours given to various seniors' groups, Guides' and Scouts' groups (including Pathfinders, Beavers, and Brownies), and school groups (homeschoolers and two Grade 7 classes at St. F. Xavier H.S.). A new initiative for teacher candidates at the University of Ottawa demonstrated how the study of birds may be used with the various Kindergarten to Grade 6 Ontario curriculums with help from Profs. Chris Tippet, Lorna McLean, and Gordon Robertson.

Mark Brenchley and Sandra Garland again sifted through submissions for attending the Youth Summit of Ontario Nature at the YMCA Geneva Park. The OFNC provided funds to send the two selected candidates, Priya Nagpal and Carlos Barbary, to the summit. Lucy Patterson and Kathy Conlan were judges at the annual Science Fair. They presented three awards (\$100) to the winning students.

This year, new logos were created by Mark Brenchley and circulated to the board and others. A small decal was produced and was sent to every member via *Trail & Landscape*. The logos are starting to appear in our various publications and will gradually replace the older (owl) logo.

Various members (Fenja, Lynn, Mark, Gillian, Lesley, Gord) held poster/promotional presentations at a number of events, including: natureScene at the Museum of Nature; Migratory Bird Day at Brewer Park; Bug Day at the Neatby Building; Healthy Trees, Healthy City for National Forest Week; Earth Day at Hunt-Club Riverside Park Community Centre; and Love thy Nature film at the Mayfair Theatre.

Lastly, the committee has begun work on producing six bilingual "storyboards" that will be placed around the Fletcher Wildlife Garden to identify seasonal flora and fauna. The storyboards will be changed three or four times during the year with changes based on what might be expected to be seen.

GORDON ROBERTSON, Chair

Events Committee

The Events Committee coordinated, planned, or supported 35 outings, five workshops, ten monthly meetings and the annual awards celebration. Topics included: birds (14), botany

(seven), butterflies and moths (four), geology (three), photography (two), and general natural history (seven).

The nine monthly meetings were held in the K.W. Neatby Building of Agriculture Canada on Carling Avenue. The January business meeting was postponed until March to allow for financial returns (delayed due to circumstances beyond the club's control), and was held at the Fletcher Wildlife Garden Interpretation Centre.

Numerous popular trips returned this year, including various spring and fall outings centered on bird migration, led by repeat leaders. Some locations and trips differed from the usual fare as well, including a trip to Luskville Caves, and a trip to the Lost Bay Nature Reserve, hosted by Ontario Nature staff. For the third year in a row, the MacSkimming Outdoor Education Centre hosted a mushroom outing, which continues to be very popular. Two fall geology-themed hikes were also well received.

The Club's biannual trip to Pelee was a sold-out success and received favourable reviews. Martha Farkas did a fantastic job as trip coordinator, and Roy John, John Cartwright, and Jon Ruddy lent their ornithological skills as leaders.

Some challenges continue, most notably the competing demands for the time of would-be leaders, which seem to be ever growing. This makes commitments for outings difficult to make at all, and most especially with the lead time required by our planning and publication cycle. Unfortunately, these time constraints led to fewer outings being offered in the summer and fall than what was desired. Nature sometimes intervenes to make this worse – a few trips were cancelled due to poor weather, including the only trip of 2016 specifically oriented towards reptiles and amphibians.

Another challenge is membership participation. Waivers returned from trips reveal that non-member attendance is high, frequently from 25% to 50% of the attendees on a given outing. On one outing, 100% of those in attendance (other than the leader) were non-members. Active, participating members are seen as a valuable base for recruiting and developing new leaders.

Committee members in 2016 were Holly Bickerton, Julia Cipriani, Hume Douglas, Margaret Hart, Sue Milks, and Jakob Mueller (Chair), with excellent support from Owen Clarkin, Chair of Conservation.

If you have ideas for events or would like to lead an outing or event, please contact Jakob Mueller (jm890_7 AT hot mail.com) or other members of the committee.

JAKOB MUELLER, Chair

Finance Committee

The Club is in a solid financial position as a result of the Czakas bequest. The final disbursement from the estate was done and the estate accounts have been closed. A big thank you to Ken Young for the enormous amount of work required to handle the settling of this estate. In total \$1.2 million was received. These funds form part of the general finances of the club and are not treated as a separate fund. A review was prepared for the Board in November showing that, as a result of the bequest, about \$600,000 had been spent or planned on various projects to further the objectives of the club.

The investments of the club were \$1.5 million at the end of the fiscal year, September 2016. The current lower interest rates have been partially offset by the increased amount invested. The Finance Committee decided to instruct Welch LLP, the financial reviewer, that it would not be necessary to list all the investments in the financial statements. The growing list has

made this a bit unwieldy. The details will be available to any member who wishes to see them.

Because of the improved financial situation of the club, the Finance Committee recommended to the Board that the honoraria should be increased for *The Canadian Field-Naturalist* Editor, Assistant *Canadian Field-Naturalist* Editor, and *Trail & Landscape* Editor.

The budget for 2016–17 was prepared. The draft was presented to the Board in September and approved in October. It estimated a shortfall of revenues over expenses of \$114,000. This includes the renovation of the pond at the Fletcher Wildlife Project which was expected to take place mostly during FY2016–17. In the event, the work went more quickly than expected, so the bulk of the cost (about \$51,000) will be included in the expenses of FY 2015–16.

The Treasurer, Ken Young, has been working with a new bookkeeper. The intention is to have this bookkeeper assume more duties such as the preparation of cheques and charitable receipts. Ken Young will be stepping down in January 2017. Ann MacKenzie has been shadowing him in preparation for assuming the duties. Remy Poulin will be taking over investment management from Ann at the same time.

REMY POULIN, Chair, Finance Committee

Fletcher Wildlife Garden

2016 has been a very productive and rewarding year for the Fletcher Wildlife Garden. The positive comments from an ever increasing number of visitors to the Fletcher indicate that our efforts are appreciated and valued. Walkers, birders, nature lovers, sparks and beavers, and tourists to Ottawa have visited the Fletcher Wildlife Garden over the past year.

Volunteers

This year over 70 regular volunteers spent time at the Fletcher Wildlife Garden either alone or in one of our weekly work groups. Together, we amassed over 5300 hours of volunteer time. The time put in by individuals assigned a “work node” should be acknowledged. Work groups from Price Waterhouse Coopers, Carleton University, Ernst and Young, and Health Canada helped supplement our regular volunteer effort. At the end of the season, a volunteer questionnaire was sent out to all volunteers. The responses indicate a very high satisfaction level with their “Fletcher experience”. Suggestions were also made on how we can do better. Certificates of appreciation were handed out by the Fletcher Wildlife Garden Management Committee to Tony Denton, Henry Steger, Malcolm Leith, Marilyn Ward, Gretchen Denton, Diane Lepage, and David Hoben acknowledging the long term service of these volunteers at the Fletcher Wildlife Garden.

Back Yard Garden

The Back Yard Garden was again a popular part of the Fletcher Wildlife Garden. New flower name signs were purchased and put in place that listed the common English and French names, and the botanical name of each plant. The colour and size of the signs were popular with photographers, and helped further our goal of public education. This summer it was decided to leave up the bird feeder in the Back Yard Garden. The large number and variety of birds attracted to the feeder proved that the decision to feed birds year round was a good one. A landscape architect and an arborist visited the Back Yard Garden in the fall and a list of suggestions – particularly related to large tree removal – was drawn up. Removal of some trees is planned for the winter (2016/17).

Amphibian Pond

The dredging and removal of sediment from the Amphibian Pond was completed in early fall. Replanting of this area will begin in the spring of 2017. A stable crushed stone pathway now encircles the pond. Strategies are being discussed to prevent dogs from entering the pond, particularly near the bridge.

Butterfly Meadow

Again this year, the butterfly meadow was the site of a variety of colours throughout the summer. A small number of different butterflies were observed this year. However, in spite of increased plantings of milkweeds, no Monarchs were seen. Work was completed on a small pond at the edge of the meadow.

Old Woods

Again this year work in the Old Woods focused on planting of new trees, bushes and flowers as this part of the Garden transitions from a grove of diseased ash trees. It would appear that diligent weeding, selective planting, and natural new growth are preventing – so far – the Woods from being taken over by Dog-strangling Vine.

Plant Sale

We had many repeat customers again this year at our plant sale. At the end of the day, we deposited close to \$5000 into the Fletcher Wildlife Garden bank account.

Interpretation Centre/Sheds

An attempted break-in of the tool shed and front door of the Interpretation Centre prompted a review of our key policy. A key lock box system at the front door now provides easy access to the Interpretation Centre. A debate continues about how much internet capacity is actually needed in the Interpretation Centre, and how this can best be provided.

TED FARNWORTH,
committee representative on board of directors

Macoun Club Committee

The Committee continues to organize the activities of the Macoun Field Club by telephone and e-mail. All five Committee members were involved with Club activities and were recognized by children and parents as being leaders of the group. Eighteen meetings were held indoors, with some presentations being made by outside speakers, others by Macoun Club leaders, and a few by Macoun Club members. There were 16 field trips. The usual destinations were the Club's long-time field-trip sites (Pakenham since 1967 and the Stony Swamp study area since 1970). The Club continues to work closely with the National Capital Commission to monitor for, study, and attempt to control invasive plants in Stony Swamp. The Club also visited two leaders' properties in Lanark County. An illustrated record of all events was maintained on the Club's website (macounfieldclub.ca). Issue no. 70 of *The Little Bear* magazine, written and illustrated by Macoun Club participants, was produced, as always, in time for distribution at the Club's annual end-of-year party in June.

On three occasions, as representatives of the Macoun Club, Committee members also volunteered to provide field programs to both elementary school students and a Carleton University environmental-science class. These activities took place in the Macoun Club's Nature Study Area and at the Fletcher Wildlife Garden. Committee members also scouted out specific sites of invasive plants and tree pathogens in the Nature

Study Area, and then conducted a film crew there for the Invasive Species Centre, with credit being given to the Macoun Field Club on the resulting video.

ROBERT E. LEE, Chair

Membership Committee

The distribution of Club membership for 2016 on September 30, 2016 is shown in the table below, with the corresponding numbers shown in brackets for September 30, 2015. “Other” represent mostly affiliate organizations that receive complimentary copies of the Club’s publications. The Board implemented policy in 2014 that the family of children in the Macoun Club be given a complimentary membership to encourage interest in the Club in the longer term. Macoun Club participation stayed stable.

Membership decreased by 41 in 2016 mainly due to a decrease of 33 in Family membership within Canada. This is the first decrease since 2013.

HENRY STEGER, Chair

Publications Committee

The Publications Committee manages publication of the Club’s scientific journal *The Canadian Field-Naturalist*, the Club’s newsletter *Trail & Landscape*, and Special Publications. Publications Committee meetings were held on 5 October 2015, 24 February 2016, 1 March 2016 and 29 September 2016. Committee members were Annie Bélair (incoming Editor, *Trail & Landscape*, Dan Brunton, Carolyn Callaghan (outgoing Editor-in-Chief, *The Canadian Field-Naturalist*), Paul Catling, Barry Cottam (Book Review Editor, *The Canadian Field-Naturalist*), William Halliday (Journal Manager, *The Canadian Field-Naturalist*), Tony Gaston, Diane Kitching, Dwayne Lepitzki (incoming Editor-in-Chief, *The Canadian Field-Naturalist*), Amanda Martin (Assistant Editor, *The Canadian Field-Naturalist*), Karen McLachlan Hamilton (outgoing Editor, *Trail & Landscape*), Frank Pope, Jeff Saarela (Chair), and David Seburn.

There was considerable change in editorial roles for both of our publications this year. Carolyn Callaghan announced she would be stepping down as Editor-in-Chief of *The Canadian Field-Naturalist*, after five years in this role. Terms of reference for the position were established, and a search for a new Editor-in-Chief was initiated. Dwayne Lepitzki, of Banff, Alberta, agreed to take on this important role, and he was welcomed to the team. Carolyn and Dwayne worked together through the year and successfully and smoothly transitioned Editor-in-Chief responsibilities. Karen McLachlan Hamilton announced she would be stepping down as Editor of *Trail & Landscape*, after serving in this role for 12 years. Annie Bélair

express interest and was welcomed as incoming Editor of *Trail & Landscape*, and Diane Kitching and Barry Cottam agreed to work with Annie to help with copyediting and proofreading. Karen and Annie worked together on the smooth and successful transition of this editorial role. Both Carolyn and Karen were thanked by the committee for their dedication and service to the Club publications over many years. Mark Gawn, who in late 2015 had agreed to replace Roy John, upon his retirement, as Book Review Editor, announced he would not able to take on the role as planned. Roy graciously postponed his retirement temporarily and a search for a new Book Review Editor was initiated. Barry Cottam expressed interest and was welcomed as new Book Review Editor and as a member of the committee. William Halliday moved to Victoria, British Columbia, in late 2016, and continued serving as Journal Manager from that location. Tony Gaston resigned from the committee and as Associate Editor for *The Canadian Field-Naturalist* in late 2016, but agreed to continue managing the OFNC Research Grants program.

Canadian Field-Naturalist and Trail & Landscape

Four issues of *The Canadian Field-Naturalist* were published in this fiscal year: 129(3) (23 October 2015), 129(4) (30 January 2016), 130(1) (17 June 2016) and 130(2) (30 September 2016). In addition to the editorial transition for *The Canadian Field-Naturalist* and *Trail & Landscape*, numerous other issues were discussed and dealt with. Details of licensing and copyright for content published in *The Canadian Field-Naturalist* were clarified. Progress was made on new author guidelines for *The Canadian Field-Naturalist*. A decision was taken in early 2016 to implement a paywall for online access to *The Canadian Field-Naturalist* for current content, after providing several years of free online access to the journal. The paywall was quickly established, and a subscription (personal or institutional) is now required for access to the four most recent issues of the journal. All older content is freely accessible online. Requiring a subscription for current content will help the Club maintain the income needed to publish the journal, whereas making all older content freely available helps the Club fulfill one of its main objectives, “to diffuse information on [all fields of natural history] as widely as possible” while not cannibalizing an important part of the journal’s revenue base. *The Canadian Field-Naturalist* began publishing articles online as they were finalized, rather than waiting until an issue was complete.

The Open Journal Systems online submission system was implemented in mid-2016 to manage journal production. The Editor, Assistant Editor, and Associate Editors were provided with instructions on how to handle manuscripts in the system, and all recognized there is a learning curve. During the tran-

	CANADIAN		USA		OTHER		TOTAL	
	2016	2015	2016	2015	2016	2015	2016	2015
Individual	358	(359)	8	(9)	0	(0)	364	(368)
Family	286	(309)	0	(1)	1	(1)	287	(310)
Student	19	(20)	1	(0)	0	(0)	20	(27)
<i>Trail & Landscape</i>	2	(1)	0	(0)	0	(0)	2	(1)
Honorary	25	(24)	0	(0)	0	(0)	25	(24)
Life	41	(44)	3	(3)	1	(1)	45	(48)
Other	24	(30)	0	(0)	1	(1)	25	(31)
Macoun Club	16	(17)					16	(17)
TOTAL	771	(811)	12	(13)	3	(3)	786	(827)

sition to this new way of working, manuscripts were handled in both the traditional way and with the new online system, depending on their stage of the publication pipeline. Once fully implemented, it is expected that the online submission system will increase efficiency of all stages of the journal production process, from initial submission to publication. Ken Young, Club Treasurer, managed *The Canadian Field-Naturalist* subscriptions, page charge invoices, and budget tracking. Sandra Garland continued in her role as copyeditor for *The Canadian Field-Naturalist*, and it was recognized that additional copyediting help was needed to maintain timely production of the journal production. Efforts to identify further help in this regard were initiated.

Requests were made to have *The Canadian Field-Naturalist* content included in BioOne, a non-profit publisher that makes scientific research more accessible through full-text aggregation of journal content produced by societies, associations, museums, research institutions, and university press, and JSTOR, a digital library of academic journals, books and primary resources, but both were rejected at the present time.

Four issues of *Trail & Landscape* were produced in the current year. *Trail & Landscape* continues to be an important source of information about current and upcoming Club activities, and a significant source of documentation of regional biodiversity and conservation needs. The committee continued to evaluate the current formats (the “look and feel”) of both *The Canadian Field-Naturalist* and *Trail & Landscape*, and made progress on the re-design of both publications. Work on a new design of *Trail & Landscape* was initiated with Wendy Cotie, typesetter for *The Canadian Field-Naturalist* and a professional designer. New formats for both are expected in 2017.

The Biodiversity Heritage Library (BHL) completed digitization of a subset of back issues of *Trail & Landscape* (from the 1980s), for which the Club had earlier provided permission. This content is freely available at <http://www.biodiversitylibrary.org/bibliography/115961#/summary>, under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) licence. The issues currently available online reflect the incomplete physical holdings at the LuEsther T. Mertz Library, New York Botanical Garden, where the digitization work was carried out. The BHL continued to scan and provide access to back issues of *The Canadian Field-Naturalist* under the same or similar licence as *Trail & Landscape*, following our agreement with them to release content older than six years. As of 12 December 2016, content to the end of volume 124 was available through BHL.

Ottawa Field-Naturalists' Club Research Grants

Several individuals who received funding in the first year of the Ottawa Field-Naturalists' Club Research Grants program published summaries of their 2015 field work in *Trail & Landscape*. These were well-received by the membership, and numerous positive comments about this new initiative of the OFNC were received. 2016 was the second year of the program. Research grants support field-based research activities that reflect and promote the Club's objectives within eastern Ontario and or western Quebec, focused particularly upon the Club's study area – inside the 50 km radius from the Peace Tower in Ontario or Quebec. A total of \$15,000 is available each year to fund research proposals. The call for proposals for 2016 awards was sent around in fall of 2015, with an application deadline of 15 January 2016. The OFNC Research Grants Subcommittee (a subcommittee of the Publications Committee), comprising Owen Clarkin, Tony Gaston (Chair), and Jeff Saarela, evaluated research proposals. Eleven proposals

were received and funding was recommended for nine of them. One applicant subsequently declined the funding, and the following eight projects were funded:

1. Emily Austen, post-doctoral fellow, University of Ottawa. The ecological significance of pollen colour variation in Trout Lily (*Erythronium americanum*).
2. Julia Charlebois, M.Sc. candidate, University of Ottawa. Do invasive plants impose selection on native plants' flowering time?
3. Jean Faubert, Société québécoise de bryologie, and Alexandre Blain, FloraQuébec. Flore du parc de la Gatineau Gatineau Park.
4. Robert Forsyth, Paul Catling, independent researchers, and Annegret Nicolai, Université Rennes (France). Surveys of rare and potentially at-risk species of land snails in the Ottawa area.
5. Mary Ann Perron, Ph.D. candidate, University of Ottawa. Tracking successional development of a newly constructed riverine wetland.
6. Frederick W. Schueler and Aleta Karstad, Bishops Mills Natural History Centre. Auditory Monitoring in Eastern Ontario.
7. David Seburn, Seburn Ecological Services. Identifying new locations in eastern Ontario where the Blanding's Turtle occurs.
8. Maria Vu, M.Sc. candidate, University of Ottawa. Hormone-based spawning induction for the captive breeding and conservation of amphibians.

JEFFREY M. SAARELA, Chair

Treasurer's Annual Report, 2016

January 10, 2017

Financial Statements

The financial statements have been prepared by our accounting firm, Welch LLP. They have conducted an engagement review of our financial records. The Club financial statements are prepared using the fund method of accounting. The first table (*Statement of Financial Position*, on page 105) presents the assets and liabilities of the Club as a whole.

The remaining tables in the financial statements present the statement of operations of the general fund (page 106), the internally restricted funds (page 107) and our one endowment fund (page 106). There is also a cash flow presentation (page 106). The Notes to the financial statements explain the Club's financial policies and include some additional details about our long-term investments.

Financial Position

Our assets peaked in the previous fiscal year, when the final disbursement from the Czasak estate to the Club was made. We can expect our assets to decline regularly through the years. That is by design – we want to use our resources to further conservation of, and education about natural history. The annual reports of various committees document how we are doing so.

The major sources of revenue for the Club are membership fees, donations and bequests, and subscription charges and authors' charges for *The Canadian Field-Naturalist*. Both membership and donations rose in FY2016, but *The Canadian Field-Naturalist* revenues are down. Revenues (and expenses) are up compared to 2015 because of the Pelee trip held in 2016.

Expenses rose during the year, primarily because of projects that are now possible because of our positive financial situation. A separate report on these projects will be presented to the members at this meeting.

Budget for the 2016–2017 Fiscal Year

The Board approves the budget for the Club at the October meeting of the Board of Directors. The budget is attached to the minutes of that meeting and is available on the OFNC website where minutes of Council meetings are kept, at <http://ofnc.ca/council/minutes.php>.

This year, the budget forecasts revenues of \$113,000 and expenses of \$227,740. Therefore we are budgeting for a deficit of over \$114,000. This is overstated by about \$40,000 because it assumed that the rehabilitation of the Fletcher Wildlife Garden pond would occur this fiscal year. In fact the work was substantially completed in September 2016 and those expenses are included in FY2016. Still, the Board expects a significant deficit this year and for the foreseeable future.

Routine Events

Most of the Treasurer's duties continue from one year to the next. They include:

- filing the Charities Information Report with the Canada Revenue Agency;
- preparing T4A returns for people receiving honoraria or contract fees from the Club;

- updating the Club's information with our bank, the Canadian Imperial Bank of Commerce, and our online payments processor, PayPal;
- depositing cheques received and writing cheques to pay expenses;
- making financial reports to Council and Committees, such as for *The Canadian Field-Naturalist*, the Seedathon, the Fletcher Wildlife Garden, and the Macoun Field Club; and
- assisting the reviewer in the production of the annual financial statements.

Our investments are made according to a policy established by the Board of Directors, and implemented by a Board appointee (last year it was Ann MacKenzie) and our investment advisor, Sue Anderson of BMO Nesbitt Burns.

As in the past, we have received excellent service from our accounting firm, Welch LLP, and our reviewer, Eric Liebmann, to whom we give thanks. We have contracted with a new book-keeping firm and expect that will produce more efficient financial processes over time.

This is my last year as Treasurer. I would again like to express my appreciation for the assistance that I have received from Frank Pope, the past Treasurer; to Ann MacKenzie, who will be taking over the Treasurer's duties, and to all members of the Board and the OFNC at large.

KEN YOUNG, Treasurer

Review Engagement Report

To the members of THE OTTAWA FIELD-NATURALISTS' CLUB

We have reviewed the statement of financial position of the The Ottawa Field-Naturalists' Club as at September 30, 2016 and the statements of operations, changes in fund balances and cash flows for the year then ended. Our review was made in accordance with Canadian generally accepted standards for review engagements and accordingly consisted primarily of inquiry, analytical procedures and discussion related to information supplied to us by the club.

A review does not constitute an audit and consequently we do not express an audit opinion on these financial statements.

Based on our review, nothing has come to our attention that causes us to believe that these financial statements are not, in all material respects, in accordance with Canadian accounting standards for not-for-profit organizations.

Welch LLP

CHARTERED ACCOUNTANTS
Licensed Public Accountants

Ottawa, Ontario
December 19, 2016

The Ottawa Field-Naturalists' Club
Statement of Financial Position
September 30, 2016

	2016	2015
ASSETS		
CURRENT ASSETS		
Cash	\$ 52,572	\$ 383,267
Short-term investments (note 4)	167,568	145,803
Amounts receivable	24,167	89,226
Prepaid expenses	721	1,079
	<u>245,028</u>	<u>619,375</u>
LONG-TERM INVESTMENTS (note 4)	1,315,478	998,347
	<u>\$1,560,506</u>	<u>\$1,617,722</u>

LIABILITIES AND FUND BALANCES		
CURRENT LIABILITIES		
Accounts payable and accrued liabilities	\$5,120	\$2,755
Deferred revenue	14,927	12,481
	<u>20,047</u>	<u>15,236</u>
FUND BALANCES		
General fund	1,256,548	1,298,752
Internally restricted funds	245,847	266,112
Martha Camfield endowment fund	38,064	37,622
	<u>1,540,459</u>	<u>1,602,486</u>
	<u>\$1,560,506</u>	<u>\$1,617,722</u>

Approved by the Board:

..... President

..... Treasurer

The Ottawa Field-Naturalists' Club
Statement of Operations and Changes in Fund Balance
– General Fund
Year Ended September 30, 2016

	2016	2015
REVENUES		
Membership fees	\$ 28,596	\$ 28,243
Bequests	–	973,781
Donations	9,520	4,124
The Canadian Field-Naturalist		
– subscription revenue	17,203	22,255
– author charges	29,051	41,487
Pelee trip	21,628	–
Interest	34,998	21,943
Advertising	200	675
Gain on foreign exchange	1,183	2,408
Other	412	1,346
	<u>142,791</u>	<u>1,096,262</u>
EXPENSES		
OPERATING:		
Affiliation fees	401	422
Bookkeeping	4,405	2,424
Courier and postage	–	797
Insurance	1,751	1,728
Interest and bank charges	1,036	1,379
Membership	1,411	1,201
Professional fees	4,350	2,723
Website	2,100	2,000
General and miscellaneous	918	2,237
	<u>16,372</u>	<u>14,911</u>
ACTIVITY:		
The Canadian Field-Naturalist	53,642	76,857
Fletcher Wildlife Garden	14,126	6,010
Awards committee	185	523
Soiree – net	1,071	518
Birds committee	3,135	5,554
Donations	16,100	214,500
Education and publicity	10,391	11,441
Excursions and lectures	737	136
Macoun Club	358	137
Pelee trip	20,457	
Trail and Landscape	11,591	8,059
Research grants	13,735	11,369
	<u>145,528</u>	<u>335,104</u>
TOTAL EXPENSES	<u>161,900</u>	<u>350,015</u>
EXCESS (DEFICIENCY) OF REVENUE OVER EXPENSES	(19,109)	746,247
FUND BALANCE, BEGINNING OF YEAR	<u>1,298,752</u>	<u>552,505</u>
	1,279,643	1,298,752
Inter-fund transfer – internally restricted funds	<u>(23,095)</u>	
FUND BALANCE, END OF YEAR	<u>\$ 1,256,548</u>	<u>\$ 1,298,752</u>

The Ottawa Field-Naturalists' Club
Statement of Changes in Fund Balance – Martha
Camfield Endowment Fund
Year Ended September 30, 2016

	2016	2015
FUND BALANCE, BEGINNING OF YEAR	\$ 37,622	\$ 37,063
Interest earned	<u>442</u>	<u>559</u>
FUND BALANCE, END OF YEAR	<u>\$ 38,064</u>	<u>\$ 37,622</u>

Note: The interest above represents half of the interest generated by the fund and is re-invested in the capital of the fund. The other half of the interest generated by the fund is recognized as interest revenue of the Macoun Fund (see Statement of Operations and Changes in Fund Balances – Internally Restricted Funds) and is made available for the use of the Macoun Field Club.

The Ottawa Field-Naturalists' Club
Statement of Cash Flows
Year Ended September 30, 2016

	2016	2015
Cash Flows from Operating Activities		
Net revenue (expenses) – all funds	\$(62,469)	\$ 751,022
Adjustments for:		
Investments – amortization		
of bond discounts	(25,377)	(18,095)
– interest accrual		
on GIC's	(12,250)	(4,965)
– donated securities	(1,002)	–
– gain on sale		
of investments	(17)	–
Change in the level of:		
Amounts receivable	65,059	(72,424)
Prepaid expenses	358	2,734
Accounts payable and accrued liabilities	2,365	(627)
Deferred revenue	<u>2,446</u>	<u>(472)</u>
	<u>(30,887)</u>	<u>657,173</u>
Cash Flows from Investing Activities		
Purchase of investments	(447,501)	(723,905)
Proceeds from sale and maturity of investments	<u>147,251</u>	<u>221,320</u>
	<u>(300,250)</u>	<u>(502,585)</u>
Cash Flows from Financing Activities		
Endowment interest earned	<u>442</u>	<u>559</u>
Increase (Decrease) in Cash	(330,695)	155,147
Cash at Beginning of Year	<u>383,267</u>	<u>228,120</u>
Cash at End of Year	<u>\$ 52,572</u>	<u>\$ 383,267</u>

(See accompanying notes)

PREPARED WITHOUT AUDIT

The Ottawa Field-Naturalists' Club
Statement of Operations and Changes in Fund Balances – Internally Restricted Funds
Year Ended September 30, 2016

	General Reserve for Contingencies	Fletcher Wildlife Garden Fund	Manning Fund	Seedathon Fund	Ann Hanes Memorial Fund	De Kiriline Lawrence Fund	Macoun Funds	2016 Total	2015 Total
Revenues									
Donations and bequests	\$	\$ 1,647	\$	\$ 607	\$ -	\$	\$	\$ 2,254	\$ 3,808
Fundraising		4,875					442	4,875	4,866
Interest			3,095	-	-			3,537	4,408
		6,522	3,095	607			442	10,666	13,082
Expenses									
Habitats		51,689						51,689	4,656
Fundraising		671						671	525
Seed				1,140				1,140	1,295
Other							526	526	1,831
		52,360	-	1,140	-	-	526	54,026	8,307
Net Revenues (Expenses)		(45,838)	3,095	(533)			(84)	(43,360)	4,775
Fund Balances, Beginning of Year	100,000	14,387	131,811	828	521	13,384	5,181	266,112	261,337
	100,000	(31,451)	134,906	295	521	13,384	5,097	222,752	266,112
Inter-Fund Transfers General*		46,711	(23,616)	-				23,095	
Fund Balances, End of Year	\$ 100,000	\$ 15,260	\$111,290	\$ 295	\$ 521	\$ 13,384	\$ 5,097	\$245,847	\$266,112

*\$46,711 was transferred from the general fund to cover the pond rehabilitation costs.
\$23,616 was transferred to the general fund to cover a portion of the author charges relating to the Canadian Field-Naturalist for the last two years.

The Ottawa Field-Naturalists' Club

Notes to the Financial Statements

Year Ended September 30, 2016

1. Purpose of Organization and Tax Status

The Ottawa Field-Naturalists' Club (the "club") is a volunteer, registered charitable organization incorporated under the Corporations Act of the Province of Ontario. The objectives of the club are to promote the appreciation, preservation, and conservation of Canada's natural heritage and to encourage investigation and dissemination of the results of research in all fields of natural history.

The club's operations are overseen by a Board of Directors (the "board"). Club activities are undertaken by club members participating in standing committees.

As a registered charity the club is exempt from income taxes by virtue of section 149(1)(f) of the Income Tax Act (Canada).

2. Significant Accounting Policies

Basis of accounting

These financial statements have been prepared in accordance with Canadian accounting standards for not-for-profit organizations.

Revenue recognition

- (i) Membership fees are recognized as revenue proportionately over the fiscal year to which they relate. The club's membership year is January 1 to December 31. The portion of membership fees that are received but not yet recognized as revenue are recorded as deferred revenue.
- (ii) The club follows the deferral method of accounting for contributions. Restricted contributions are recognized as revenue in the year in which the related expenses are incurred. Unrestricted contributions are recognized as revenue when received or receivable if the amount to be received can be reasonably estimated and collection is reasonably assured. Endowment contributions are recognized as direct increases in net assets. The club only recognizes revenue from bequests if the will has been probated, a valuation has been received from the executor of the estate and collection can be reasonably assured. Otherwise, revenue from bequests will be recognized as the amounts are received.
- (iii) Subscription revenue and author charges are recognized as revenue at the time of release and shipment of the related Canadian Field-Naturalist publication. The liability for the portion of subscription revenue and author charges invoiced in advance of the release and shipment of the related publication is recorded as deferred revenue.
- (iv) Trip revenue is recognized at the conclusion of the related field trip. Amounts collected in advance of field trips that have not yet taken place is recorded as deferred revenue.
- (v) Interest income comprises interest from cash and investments. Interest on investments is recognized

over their term using the effective interest method. Interest income derived from the investment of restricted contributions, where the contribution agreement specifies that the investment income is restricted, is accounted for the same manner as the restricted contributions.

- (vi) Advertising revenue is recognized in the period in which the advertisement is published.
- (vii) Fundraising revenue is included in the statement of operations upon completion of the fundraising event.
- (viii) Other revenue includes royalties and the sale of other products and services. Revenue from royalties is recognized in accordance with the terms of the related agreement. Revenue from the sale of other products and services is recognized at the time of delivery or when the service has been rendered.

Fund accounting

The Club maintains its accounts in accordance with the principles of fund accounting. Resources are classified for accounting and reporting purposes into funds according to the activity or object specified.

General fund

The General Fund reports the revenue and expenses relating to general operations and administration activities.

Internally restricted funds

(i) General Reserve

The General Reserve for contingencies was established by the Club to fund outstanding operating expenses should the Club discontinue its operations.

(ii) Fletcher Wildlife Garden Fund

The Fletcher Wildlife Garden fund supports the habitat development at the Fletcher Wildlife Garden, with income directed donations and the proceeds for the annual plant sale.

(iii) Manning Fund

The Manning fund was established by a bequest, and the interest generated is used to assist authors to publish articles in the Canadian Field-Naturalist.

(iv) Seedathon Fund

The Seedathon fund collects donations from the annual bird sighting event and purchases seed for the Club's bird feeders.

(v) Anne Hanes Memorial Fund

The Anne Hanes Memorial fund was raised in memory of Anne Hanes, the founding editor of Trail and Landscape, and is used to finance the annual winners of the Anne Hanes Natural History Award.

(vi) De Kiriline-Lawrence Fund

The de Kiriline-Lawrence fund was funded by a bequest from the popular author of nature books, and is supplemented by annual donations and used to support conservation efforts.

(vii) Macoun Funds

The Macoun Funds comprises of two internally restricted funds, the Martha Camfield Memorial fund and the Macoun Baillie Birdathon fund. The former is used to support special projects of the Macoun Field Club, a youth club. The latter was raised from donations made during the Baillie Birdathons. Its purpose is to support bird research by a Macoun Field Club youth member.

Martha Camfield Endowment Fund

The Martha Camfield endowment fund was established by the family and friends of Martha Camfield to help continue her efforts to have children study, understand, respect and preserve their natural environment. Under the terms of endowment agreement half of the interest generated by the fund is re-invested in the capital of the fund while the other half is credited to the Martha Camfield Memorial fund and made available for use by the Macoun Field Club. In the Statement of Operations and Changes in Fund Balances - Internally Restricted Funds, the Martha Camfield Memorial Fund and the Macoun Baillie Birdathon Fund have been combined and presented as the Macoun Funds.

Internally restricted net assets

Internally restricted net assets represent the amount approved by the board to be set aside for special purposes. These amounts are not available for unrestricted purposes without the approval of the board.

Financial Instruments

The club initially measures its financial instruments at fair value upon initial recognition. The club's cash is subsequently measured at fair value. All other financial instruments are measured at amortized cost at the date of the financial statements.

Donated services

The club is dependent on the voluntary service of many of its members. As there is difficulty in determining the fair value of voluntary services, they are not recognized in these financial statements.

Use of estimates

The preparation of financial statements in conformity with Canadian accounting standards for not-for-profit organizations requires management to make estimates and assumptions that affect the reported amounts of assets and liabilities and disclosure of contingent assets and liabilities at the date of the financial statements and the reported amounts of revenues and expenses during the reporting period. Actual results could differ from those estimates.

Management makes accounting estimates in the determination of the club's potentially uncollectible amounts receivable and in the estimation of the club's accrued liabilities.

By their nature, these estimates are subject to uncertainty and the impact on the financial statements of the current future periods could be material.

3. Financial Instruments

The club is exposed to various risks through its financial instruments. The following analysis provides a measure of the club's risk exposure and concentrations as at September 30, 2016.

Credit risk

Credit risk is the risk that one party to a financial instrument will cause a financial loss for the other party by failing to discharge an obligation.

The club's maximum exposure to credit risk represents the carrying value of its cash, amounts receivable and investments totalling \$1,559,785 (2015 - \$1,616,643).

The club's cash is deposited with Canadian financial institutions. As a result, management believes the risk of loss on cash to be unlikely.

The company provides credit to authors of the Canadian Field-Naturalist publication in the normal course of operations. It carries out, on a continuing basis, a review of outstanding amounts and maintains a provision for uncollectible accounts. Management has established an allowance for doubtful amounts receivable at September 30, 2016 of \$3,100 (2015 - \$1,500) that represents management's best estimate of potentially uncollectible accounts.

Investments primarily consist of provincial bonds backed by provincial governments and guaranteed investment certificates issued by Canadian financial institutions of high credit quality. Possible changes to the credit quality of these securities exposes the club to credit risk. The club manages its exposure to this risk by holding a diversified portfolio with varied maturities.

Liquidity risk

Liquidity risk is the risk that the club cannot meet its debts when they become due. Liquidity risk also includes the risk of the club not being able to liquidate assets in a timely manner at a reasonable price.

The club meets its liquidity requirements by monitoring its expected future cash flow requirements and holding a significant amount of assets that can be readily converted into cash.

Market risk

Market risk is the risk that fair value or future cash flows of a financial instrument will fluctuate because of changes in market prices. Market risk is comprised of currency risk, interest rate risk and other price risk.

(i) *Currency risk*

Currency risk refers to the risk that the fair value of financial instruments or future cash flows associated with the instruments will fluctuate relative to the Canadian dollar due to changes in foreign exchange rates.

Approximately \$5,000 (2015 - \$2,500) of club's cash is denominated in U.S. currency. However, the club primarily transacts in Canadian dollars and so management does not believe the club is exposed to significant currency risk.

(ii) *Interest rate risk*

Interest rate risk refers to the risk that the fair value of financial instruments or future cash flows associated with those instruments will fluctuate due to changes in market interest rates. The club's exposure to interest rate risk arises from its interest bearing assets.

The club’s cash includes amounts on deposit with Canadian financial institutions that earn interest at market rates. Fluctuations in market rates of interest on cash do not have a significant impact on the club’s financial operations.

The club manages the interest rate risk of its investments by the implementation of prudent investment policies. The club’s investments in bonds mature at face value on a staggered basis over the next 14 years. The laddered structure of the maturities helps to enhance the average portfolio yield while reducing the sensitivity of the portfolio to the impact of interest rate fluctuations. Effective interest rates to maturity for these securities range from 1.65% to 4.40% (2015 – 2.58% to 4.40%).

4. Investments

Short-term investments are comprised of:

Guaranteed investment certificates
Bonds

Long-term investments are comprised of:
Guaranteed investment certificates
Bonds

(iii) Other price risk

Other price risk refers to the risk that the fair value of financial instruments or future cash flows associates with the instruments will fluctuate because of changes in market prices (other than those arising from currency risk or interest rate risk), whether those changes are caused by factors specific to the individual instrument or its issuer or factors affecting all similar instruments traded in the market.

The club is not exposed to other price risk.

Changes in risk

There have been no changes in the club’s risk exposures from the prior year.

	2016		2015
	Market Value	Amortized Cost	Amortized Cost
Guaranteed investment certificates	\$ 139,378	\$139,378	\$ 85,756
Bonds	28,252	28,190	60,047
	<u>\$ 167,630</u>	<u>\$167,568</u>	<u>\$ 145,803</u>
Long-term investments are comprised of:			
Guaranteed investment certificates	\$ 492,107	\$492,107	\$ 438,467
Bonds	867,589	823,371	559,880
	<u>\$1,359,696</u>	<u>\$1,315,478</u>	<u>\$ 998,347</u>

Ottawa-Carleton District School Board (OCDSB)
Outdoor Education Centres

The club has made a commitment to donate \$5,000 annually from 2016 to 2020 to the OCDSB with the expressed purpose of supporting the OCDSB Outdoor Education Centres (Bill Mason & MacSkimming Centres). The primary goal of the commitment is to enable more students that do not otherwise have the financial means to spend time at the Outdoor Education Centres and to provide learning opportunities and experiences that will allow students to better understand their natural world.

Fletcher Wildlife Garden

The club is committed to maintain the Fletcher Wildlife Garden, a 6.5 hectare property on the Central Experimental Farm in Ottawa, Ontario. The club relies on the voluntary contributions from club officers and members in order to fulfill this commitment. As described in note 2, the fair value of contributed human resources are not recognized in these financial statements.

7. Comparative Figures

Certain comparative figures have been reclassified where necessary to conform to the presentation adopted in the current year.

A portion of the club’s investments totalling \$38,064 (2015 – \$37,622) are restricted for endowment purposes. The club has not segregated and identified any particular investment as being held for endowment purposes. Rather, the club allocates a portion of the total interest generated during the year on all of its investments to the endowment fund based upon the opening endowment fund’s balance in comparison to the club’s opening net assets.

5. Capital Assets

No capital assets have been expensed and included in the statements of operations in either the current or preceding fiscal year.

6. Commitments

Life memberships

The club is committed to provide for regular membership benefits to lifetime members. Since it is not practicable to determine the total liability associated with providing these benefits for the rest of the lives of these individuals, the annual costs are expensed as incurred. Lifetime memberships are no longer offered by the club. As of September 30, 2016, there were 48 (2015 – 48) remaining lifetime members.

The Ottawa Field-Naturalists' Club Awards for 2016, presented February 2017

ELEANOR ZURBRIGG, IRWIN BRODO, JULIA CIPRIANI, CHRISTINE HANRAHAN and KAREN McLACHLAN HAMILTON

On February 25th, 2017 members and friends of the Ottawa Field-Naturalists' Club gathered for the Club's Awards Night at St. Basil's Church in Ottawa to celebrate the presentation of awards for achievements in the previous year. Awards are given to members or non-members who have distinguished themselves by accomplishments in the field of natural history and conservation or by extraordinary activity within the Club. Five Club awards were presented for 2016, for: (1) further-

ing the knowledge of botany in Canada and internationally, (2) supporting communications activities of the Club, (3) long time service for the Club's online communications and Fletcher Wildlife Garden project, (4) habitat enhancement by engaging students in nest box construction, and (5) modifying habitat to help juvenile Snapping Turtles in Ottawa.

As well, a President's Prize was presented in recognition of unusual support of the Club's scientific journal.

Honorary Member: John McNeill

This award is presented in recognition of outstanding contributions by a member or non-member to Canadian natural history or to the successful operation of the Club. Usually people awarded an honorary membership have made extensive contributions over many years.

It is a pleasure to award Honorary Membership in the Ottawa Field-Naturalists' Club to Canadian-Scottish botanist John McNeill. Long recognized as an international authority on vascular plant taxonomy and nomenclature, Dr. McNeill has also served important roles in academic and research institutions in both Ottawa and Toronto.

John McNeill was born in Scotland and earned his doctorate at the University of Edinburgh. After serving as a Lecturer at the University of Reading and University of Liverpool from 1957–1969, he came to Ottawa having accepted a position at the Plant Research Institute of Agriculture Canada (now called Agriculture and Agri-food Canada [AAFC]), and so began his long and productive period as a Canadian research botanist. Dr. McNeill contributed a great deal to the development of the plant systematics unit of AAFC and authored many papers on Canadian plants. One of his best known is "Grasses of Ontario" with William Dore. That monumental work may never have been completed without McNeill's collaboration. Other important titles concerning Canada were "The conservation of evolutionary centres in Canada", "The genus *Atriplex* in Canada", and several papers on the genus *Polygonum*. He also is an expert on the evolution of weeds and he contributed to the first complete inventory of Canadian weeds. During his years at the Central Experimental Farm in Ottawa, his door was always open to the professional and non-professional alike. He has always been both patient with enquiries and generous in his contributions to the work of others.

John McNeill is not only an accomplished researcher but also an extraordinary teacher, always ready to share his expert and vast botanical knowledge with anyone in need. In 1978 he took a short work transfer to the University of Toronto to assist in teaching plant systematics

when the program was without staffing. In 1981, he left AAFC to become Professor and Chair of the Department of Botany at the University of Ottawa. One of his Master's degree students at the U of O was Laurie Con-saul, who became an accomplished botanist and was an avid birder well known to members of the Ottawa Field-Naturalists' Club.

Dr. McNeill returned to Scotland in 1987 to serve as Regius Keeper (Director) of the Royal Botanical Garden in Edinburgh. Only a few years later, he returned to Canada to teach at the University of Toronto and serve as Assistant Director of the Royal Ontario Museum, later becoming Director, and, in 1995, President of that institution. He remains Emeritus Director of the ROM.

Aside from his profound influence on hundreds of Canadian students and many Canadian botanists through his academic work, John McNeill served Canadian botany and the international botanical community as an expert on matters of biostatistics and botanical nomenclature. Any botanist anywhere in the world who has dealt with the names of plants using the International Code of Botanical Nomenclature, the global 'rule book' for the official naming of plant taxa, has benefitted from John McNeill's contributions in that field. As a Canadian botanist of international renown, he is rightly a major source of national pride.

Most recently, Dr. McNeill has been a major contributor to the on-going Flora of North America project, providing particularly critical input in two large and complex groups of plants, Caryophyllaceae (Pink Family) and Polygonaceae (Knotweed Family).

In 1999, he retired from the ROM and returned once again to Edinburgh where he has maintained a remarkably full program of pure and applied taxonomic research as Honorary Research Associate of the Royal Botanical Gardens, often doing editorial work with the journal, *Taxon*, dealing especially with nomenclatural issues, and, most significantly, he continues to play a large role in the revision and management of the International Code of Botanical Nomenclature and is the

senior author of the current (Melbourne 2011) edition of the Code.

This combination of contributions both to science and to the research process itself on a regional, national, and global scale is remarkable if not unique. That in addition John McNeill has inspired and assisted the careers and discoveries of others makes his contribution to Canadian natural sciences all the more impressive.

OFNC Honorary Membership is appropriate for this long-time member of the Ottawa Field-Naturalists' Club (since 1970), acknowledging his impact on Canadian botany through his own publications and those of his Canadian students, as well as his international reputation as a leader on matters concerning botanical nomenclature.

(Prepared by Dan Brunton and Irwin Brodo, with assistance of Paul Catling and Jacques Cayouette)

Member of the Year: Gordon Robertson

The Member of the Year award recognizes a member judged to have contributed the most to the Club in the previous year.

We are recognizing Gordon Robertson as Member of the Year for his enthusiastic and willing support of a number of Club activities in 2016.

In 2016, Gordon took on the duties of Chair of the Education and Publicity Committee. He also undertook a number of activities on behalf of the committee. He has been extremely generous in response to requests to the OFNC from community groups for a nature talk or nature walk. These requests come in via the Club's website which invites people to email their request to education@ofnc.ca, which is directed to Gordon.

Gordon created slideshows on various topics: migratory birds, waterbirds, butterflies, the Monarch Butterfly, and there are others. He delivered two workshops at the Fletcher Wildlife Garden (FWG) – one was for University of Ottawa education students and the other was for U of O teacher candidates. He gave nature talks to two grade seven classes at St. Francis Xavier High School. As well he co-staffed the OFNC display at several venues including Bug Day 2016 and at the Canadian Museum of Nature's NatureScene symposium.

Gordon led a number of nature walks, which when the walk was for kids, became a scavenger hunt. He led a nature walk through McCarthy Woods for the Riverside Park Community and Recreation Association, a

nature walk co-led by Jakob Mueller for Friends of Petrie Island, a nature activity for a Mini Wheats camp (kids) at Watson's Mill, a nature walk for Girl Guides and Scouts in Winchester, and nature outings at the FWG for each of Brownies, Beavers, and homeschoolers.

Gordon also played an active role at the FWG, participating on the Management Committee, helping the Friday morning work crew, co-maintaining the bird feeders, maintaining the computer, and helping with many other tasks as needed. Over the past year, Gordon developed several posters for the FWG outdoor bulletin boards, and he is leading the creation of seasonal interpretive panels (storyboards) to be displayed at several locations in FWG.

Gordon also monitors the Club's Facebook posts fairly regularly and serves as liaison between the Facebook Group's administrators and the OFNC Board of Directors.

He attended the fall meeting of the Ontario Nature Eastern Region Network held at the Quinte Conservation Area and will be the OFNC's representative on this network.

It is for his enthusiastic contributions to many Club activities that we are recognizing Gordon Robertson with the Member of the Year Award for 2016.

(Prepared by Eleanor Zurbrigg with input from Lynn Ovenden)

George McGee Service Award: Sandra Garland

This award is given in recognition of a member who has contributed significantly to the smooth running of the Club over several years.

Sandra Garland has been involved with the OFNC for many years and in many capacities. She has been active in the Publications, Fletcher Wildlife Garden, Computer Management committees, as well as in several *ad hoc* groups. Her contributions have been vast; however, the Club would like to highlight four of her outstanding accomplishments.

In 1997 Sandy responded to an ad in *Trail & Landscape* looking for someone who was "fully conversant with HTML, and [could] surf the web in their sleep". From that point on, Sandy became known as the OFNC Webmaster. Her initial duties were to develop and coordinate committee sites, and to "perhaps provide inter-

linking via an OFNC website". It began as an information hub where she would update the site with material submitted by members of the various committees. That was 20 years ago, and things change over time. She continues to update the website regularly, but she also writes and edits articles posted on the OFNC blog and the Fletcher Wildlife Garden newsletter. She routinely fields queries submitted to the OFNC and will respond directly if she knows the answer or, if not, will forward the question to the right person. Thanks to Sandy, people receive answers as promptly as possible. She has also co-administered the Club's Facebook Group which has more than 1000 members. The hope in 1997 was to have a site that was dynamic, with continuous updates and new material posted regularly. Sandy has accomplished precisely that.

Sandy is the force behind the Fletcher Wildlife Garden's annual Native Plant Sale. Her expertise and efforts to produce hundreds of native plants allow people to plant them in their gardens without destroying a patch in nature. Preparation for the sale begins in the fall when seeds are collected from Fletcher and some nearby sites. The seeds are then either stored indoors or potted and planted in the outdoor nursery. In January, the stored seeds are potted and propagated at the Interpretive Centre. From January to April, Sandy ensures that they have the proper light, moisture, and temperature requirements for producing healthy plants. If conditions are not right, the plants die leaving very little for the sale.

The devastation of the Old Woodlot after the Emerald Ash Borer moved through was immense. After 57 dead trees were removed, a number of non-native plants, such as burdock and Motherwort, took off. Then there is the continuous battle with Garlic Mustard and Dog-strangling Vine. The Old Woodlot desperately needed revitalizing, but it seemed like such a daunting task. Sandy accepted the challenge. She, on behalf of the Club, began by selecting nine native tree species from the Ferguson Forest Nursery, to be planted in the area. Then, on Tuesday afternoons, she coordinated the weekly volunteer duties that ranged from removing large non-native plants and invasives, to planting trees,

shrubs, and wildflowers, to hunting down saplings planted the previous year that were engulfed by weeds.

A new strategy for tackling large or difficult projects was recently adopted at the FWG. The strategy is to create "nodes", a place or feature where volunteers work to create, preserve, or protect the flora and fauna within. A node is small enough that a volunteer can work on it independently and will be able to see results within a short period of time. Examples include: brush piles, Dog-strangling Vine "crop circles", or the insect motel. It was Sandy who volunteered to become the coordinator of the node-nanny group where she solicited volunteers and would help them get started on their various nodes. She became the Tuesday afternoon go-to person who would welcome the node nannies, open the sheds, and chat with them about their goal for the day and a strategy of achieving that goal.

If all of the above is not enough, Sandy continues to support public outreach at the FWG and, more recently, has taken on the duties of Copy Editor for *The Canadian Field-Naturalist*.

Awarding the George McGee Service Award to Sandy Garland is a fitting response to her long and dedicated service to the Ottawa Field-Naturalists' Club. Congratulations Sandy!

(Prepared by Karen McLachlan Hamilton)

Conservation Award – Member: Richard Waters

The Conservation Award – Member is given in recognition of an outstanding contribution by a member in the cause of natural history conservation in the Ottawa Valley, with particular emphasis on activities within the Ottawa District.

For 2016 we are recognizing the impact Richard Waters has had on the Bell High School students in his grade nine Exploring Technology class. As a teacher, his challenge was to generate students' interest to make something that they would be proud enough of to take home with them and to get their credit for grade nine Exploring Technology as required by the Ontario curriculum. The outcome of his work with over 1000 students since 2008 is a great deal of pride in their creations and an interest in birding – feeding, housing, and protecting the birds' habitats.

The seeds of Richard's work with the students were planted by Chris Traynor of the Ottawa Field-Naturalists' Club and Chris Bruce of the Macnamara Field Naturalists' Club. Chris Traynor mentioned to Richard that there was a need to replace some owl boxes that were falling apart after 20 years of service. Chris Bruce suggested that Richard's students make Eastern Bluebird boxes for the Bell Arena Woods area behind the high school.

Richard guides his students through a process to identify a local species and to investigate their habitat. The students generate a design specification for the outcome they are looking for and identify performance

criteria. He teaches students to draw designs of the nest box in two dimensions and in three dimensions, to produce a plan, to use the tools, materials, and machinery in the shop, and guides them through to a finished product.

Richard oversees the process, drawing on the help and advice of his local birding network at Innis Point Bird Observatory and fellow OFNC birders for input on types of boxes and location to target conservation needs. Finding suitable habitat for species in need is important. Locations have to be accessible, yet out of sight to avoid vandalism or disturbance. Richard and his team monitor a constantly growing number of boxes throughout the year. Richard provides feedback and photos to the students. Some students have continued an interest. Richard has them count birds twice a week for the FeederWatch project!

Richard and his students have been successful in providing boxes for a growing list of species, which includes Purple Martin, with a grant from World Wildlife Fund and Loblaw Ecogrant (\$850), Eastern Bluebird, Eastern Screech Owl, White-breasted Nuthatch, Tree Swallow, House Wren, Downy Woodpecker, Red-bellied Woodpecker, bee boxes, and flying squirrels' nesting boxes. They have installed a web cam for Bell High School's FeederWatch project with live footage streamed into the Science and Technology classrooms via the school's network.

Upcoming projects for which Richard and his students have created designs and bid proposals include tree planting, outdoor classrooms, and butterfly gardens.

We are pleased to recognize the work of Richard Waters with this Conservation Award for a member.

Richard's students' creations may be seen at http://www.pbbase.com/rwaters/purple_martin_house_project&page=all.

(Prepared by Julia Cipriani)

Conservation Award – Non-Member: City of Ottawa

This award is given in recognition of an outstanding contribution by a non-member in the cause of natural history conservation in the Ottawa Valley, with particular emphasis on activities within the Ottawa District.

This year the award goes to the City of Ottawa's planning and environmental engineering groups for their efforts to help hatchling Snapping Turtles make it safely to Mud Lake at the Britannia Conservation Area. Snapping Turtles are officially listed as a species at risk federally and provincially.

It has been known for quite some time that the hatchling Snapping Turtles were being killed on the road to the water filtration plant at the Britannia Conservation Area. Female Snapping Turtles emerge from the lake every June to lay their eggs. Although they may head in any direction, many travel north from the lake and lay their eggs in the gardens and open areas around the filtration plant. Every fall the eggs hatch and the tiny hatchlings head for the lake – or sometimes away from it.

While those hatchlings from nests close to the lake need travel only a few metres, others must cross the road to reach Mud Lake. Being hit by a car is always a danger, but much more problematical was the road's curb. Although the turtles could tumble down the curb and cross the road, they could not get up and over the curb on the other side by the lake and were trapped on the road.

The curb was only about 14 cm tall, but from the viewpoint of a 3-cm-long hatchling, it was an insurmountable cliff. Hatchlings could follow the curb and, maybe, find a gap, but this might be 25 m away. Many died from dehydration under the hot sun on the road – or were eaten.

The OFNC Conservation Committee began working with the city on this issue in early 2015, and a solution was put in place in autumn 2015. The city removed the vertical curbs along the south side of the road and replaced them with sloped curbs. The gradual slope means that hatchling Snapping Turtles can now cross the road and continue their trek to Mud Lake. During autumn 2016, hatchling turtles were observed using the new curbs to safely reach Mud Lake.

We applaud the City of Ottawa, working with the Britannia Water Purification Plant, for their quick response to this issue, which goes a long way to helping more of the at risk Snapping Turtles survive.

For their positive and speedy response to concerns regarding safety of Snapping Turtles at Britannia Conservation Area, the OFNC is honored to present the City of Ottawa's planning and environmental engineering groups with its Conservation Award for a non-member.

(Prepared by Christine Hanrahan based on material from David Seburn found at <https://ofnc.wordpress.com/2015/11/13/victory-for-the-snapping-turtles>)

President's Prize: Carolyn Callaghan

This award is given at the President's discretion in recognition of a member for unusual support of the Club and its aims.

I would like to acknowledge Carolyn Callaghan for exceptional accomplishments during her tenure as Editor-in-Chief of *The Canadian Field-Naturalist* (the CFN).

Carolyn served as Editor from 2011 to 2016, leading production of volumes 125 to 130(1), and as outgoing Editor-in-Chief for volume 130(2–3) during the smooth transition to a new Editor. For some six years, beginning in 2010, Carolyn successfully led a large team including two Assistant Editors, a Book Review Editor, a Tributes Editor, multiple Associate Editors, Copyeditors, a typesetter, and two webmasters, while working closely with the OFNC Publications Committee and the OFNC Board of Directors, and engaging with hundreds of communicating authors of manuscripts and peer reviewers.

Carolyn returned the CFN to a regular schedule of publication, and under her editorship the journal made the transition to electronic publishing in addition to the standard hard-copy version of the journal.

Carolyn demonstrated particularly strong leadership in encouraging youth in science. She accepted for publication two papers (in volume 127(3)) reporting original research conducted by two high school students, encouraging these young scientists in their work and continuing a long OFNC tradition of mentoring young naturalists.

The job of Editor-in-Chief for a science journal is a demanding one, and Carolyn succeeded in this role for *The Canadian Field-Naturalist*. I am pleased to present her with the President's Prize.

Since June 2016, Dr. Carolyn Callaghan is a Senior Conservation Biologist with the Canadian Wildlife Federation.

(Prepared by Diane Lepage, President, based on material from Jeff Saarela)

Book Reviews

BOTANY: Vascular Plants of Alberta, part 1: Ferns, Fern Allies, Gymnosperms, and Monocots	80
ZOOLOGY: Ecology of Salmonids in Estuaries around the World: Adaptations, Habitats, and Conservation — Heart of a Lion: A Lone Cat’s Walk Across America	81
OTHER: Blooms: An Illustrated History of the Ornamental Gardens at Ottawa’s Central Experimental Farm Best Places to Bird in British Columbia – The Carbon Code: How You Can Become a Climate Change Hero Ice Blink: Navigating Northern Environmental History – Protecting the Planet: Environmental Champions from Conservation to Climate Change – Alexander Wilson: Enlightened Naturalist. Aperçus: Histories Texts Cultures Series	84
NEW TITLES	90

News and Comment

Upcoming Meetings and Workshops

American Ornithology 2017 — Ecological Society of America Annual Meeting —Northeast Partners in Amphibian and Reptile Conservation Annual Meeting — American Fisheries Association Meeting 51 st North American Moose Conference/Workshop	94
Ontario’s Environmental Review Tribunal overturns the Renewable Energy Approval for a second wind farm project on the grounds of serious and irreversible harm to wildlife	94
Remembering Leslie Cody	95

Minutes of the 138 th Annual Business Meeting of the Ottawa Field-Naturalists’ Club January 10, 2017	96
---	----

Club Awards	111
-------------	-----

Mailing date of the previous issue 130(4): 21 April 2017

Publication trends in <i>The Canadian Field-Naturalist</i> , 1980–2015	WILLIAM D. HALLIDAY	1
A population-level analysis of morning song: exploring the implications for point counts JENNIFER R. FOOTE, LAUREN P. FITZSIMMONS, LYNNEA M. LOBERT, LAURENE M. RATCLIFFE, and DANIEL J. MENNILL		10
Use of camera traps provides insight into the feeding ecology of Red Foxes (<i>Vulpes vulpes</i>) CASEY J. WAGNON and THOMAS L. SERFASS		19
Extinguishing a learned response in a free-ranging Gray Wolf (<i>Canis lupus</i>) L. DAVID MECH		23
Diet and prey selection of Barn Swallows (<i>Hirundo rustica</i>) at Vancouver International Airport AUDREY A. LAW, MIRANDA E. THRELFALL, BRENDON A. TIJMAN, ERIC M. ANDERSON, SEAN MCCANN, GARY SEARING, and DAVID BRADBEER		26
Evidence for the historical occurrence of wolves (<i>Canis</i> spp.) in Nova Scotia, Canada ANDREI N. WHITAKER and KAREN F. BEAZLEY		32
Edge-habitat use by Northwestern Gartersnakes (<i>Thamnophis ordinoides</i>) in Saanich, British Columbia GRAHAM P. DIXON-MACCALLUM, KATIE A. H. BELL, and PATRICK T. GREGORY		37
Inexpensive video drop-camera for surveying sensitive benthic habitats: applications from glass sponge (Hexactinellida) reefs in Howe Sound, British Columbia LENA CLAYTON and GLEN DENNISON		46
Expanded range limits of boreal birds in the Torngat Mountains of Northern Labrador DARROCH WHITAKER		55
European Skipper butterfly (<i>Thymelicus lineola</i>) associated with reduced seed development of Showy Lady's-slipper orchid (<i>Cypripedium reginae</i>) PETER W. HALL, PAUL M. CATLING, PAUL L. MOSQUIN, and TED MOSQUIN		63
A first count of Thick-billed Murres (<i>Uria lomvia</i>) and Black-legged Kittiwakes (<i>Rissa tridactyla</i>) breeding on Bylot Island ANTHONY J. GASTON, MARC-ANDRÉ CYR, and KIERAN O'DONOVAN		69
Thematic Collection: alvars in Canada DANIEL F. BRUNTON and PAUL M. CATLING		75

(continued on inside back cover)

The CANADIAN FIELD-NATURALIST

A JOURNAL OF FIELD BIOLOGY AND ECOLOGY



Volume 131, Number 2

April–June 2017

Published by THE OTTAWA FIELD-NATURALISTS' CLUB, Ottawa, Canada

The Ottawa Field-Naturalists' Club

FOUNDED IN 1879

Patron

His Excellency the Right Honourable David Johnston, C.C., C.M.M., C.O.M., C.M.
Governor General of Canada

The objectives of this Club shall be to promote the appreciation, preservation and conservation of Canada's natural heritage; to encourage investigation and publish the results of research in all fields of natural history and to diffuse information on these fields as widely as possible; to support and cooperate with organizations engaged in preserving, maintaining or restoring environments of high quality for living things.

Honorary Members

Ronald E. Bedford
Charles D. Bird
Fenja Brodo
Irwin M. Brodo
Daniel F. Brunton
Michael D. Cadman
Paul M. Catling

Francis R. Cook
Bruce Di Labio
Anthony J. Erskine
J. Bruce Falls
Peter W. Hall
Christine Hanrahan

C. Stuart Houston
Ross A. Layberry
Robert E. Lee
John McNeill
Theodore Mosquin
Robert W. Nero

E. Franklin Pope
Allan H. Reddoch
Joyce M. Reddoch
Dan Strickland
John B. Theberge
Sheila Thomson

2017 Board of Directors

President: Diane Lepage
1st Vice-President: Jakob Mueller
Recording Secretary: Lynn Ovenden
Treasurer: Ann MacKenzie

Annie Bélair
Fenja Brodo
Owen Clarkin
Edward Farnworth

Diane Kitching
Dwayne Lepitzki
Rémy Poulin
Gordon Robertson

Jeffery M. Saarela
Henry Steger
Eleanor Zurbrigg

To communicate with the Club, address postal correspondence to: The Ottawa Field-Naturalists' Club, P.O. Box 35069, Westgate P.O., Ottawa, ON, K1Z 1A2, or e-mail: ofnc@ofnc.ca. For information on Club activities, go to www.ofnc.ca

The Canadian Field-Naturalist

The *Canadian Field-Naturalist* is published quarterly by The Ottawa Field-Naturalists' Club. Opinions and ideas expressed in this journal do not necessarily reflect those of The Ottawa Field-Naturalists' Club or any other agency.

Website: www.canadianfieldnaturalist.ca/index.php/cfn

Editor-in-Chief: Dr. Dwayne Lepitzki
Copy Editors: Sandra Garland and Dr. John Wilmshurst
Book Review Editor: Barry Cottam
Subscription Manager: Eleanor Zurbrigg

Assistant Editor: Dr. Amanda Martin
Typographer: Wendy Cotie
Webmaster: Dr. Bill Halliday
Author Charges Manager: Ken Young

Associate Editors:	Dr. Ron Brooks	Dr. Jennifer R. Foote	Jon McCracken	Dr. Jeffery M. Saarela
	Dr. Carolyn Callaghan	Dr. Graham Forbes	Dr. Garth Mowat	David C. Seburn
	Dr. Paul M. Catling	Thomas S. Jung	David Nagorsen	Dr. Jeffrey H. Skevington
	Dr. François Champleau	Dr. Donald F. McAlpine	Dr. Marty Obbard	

Chair, Publications Committee: Dr. Jeffery M. Saarela

All manuscripts intended for publication except Book Reviews can be addressed to the Editor and sent by e-mail: editor@canadianfieldnaturalist.ca **or postal mail (with disk):** P.O. Box 1979, Banff, AB T1L 1B7; (403) 762-0864. Online submissions through the website are encouraged.

Book-review correspondence should be sent to the Book Review Editor by e-mail: b.cottam@rogers.com **or postal mail:** 98 Norman Street, Ottawa, ON K1S 3K6

Subscriptions and Membership:

Subscription rates for individuals are \$40 (online only), \$50 (print only), or \$60 (print + online). Libraries and other institutions may subscribe for \$120 (online only or print only) or \$180 (print + online). All foreign print subscribers and members (including USA) must add \$10 to cover postage. The Ottawa Field-Naturalists' Club annual membership fee of \$40 (individual), \$45 (family), or \$20 (student) includes an online subscription to *The Canadian Field-Naturalist*. Members can receive printed issues of CFN for an additional \$30 per volume (four issues). For further details, see <http://ofnc.ca/member.php>. The club's regional journal, *Trail & Landscape*, covers the Ottawa District and regional Club events and field trips. It is mailed to Ottawa area members, and is available to those outside Ottawa on request. It is available to libraries at \$40 per year. Subscriptions, applications for membership, notices of changes of address, and undeliverable copies should be sent to subscriptions@canadianfieldnaturalist.ca or mailed to: The Ottawa Field-Naturalists' Club, P.O. Box 35069, Westgate P.O., Ottawa, ON, K1Z 1A2 Canada. Canada Post Publications Mail Agreement number 40012317. Return postage guaranteed.

The Thomas H. Manning fund, a special fund of the OFNC, established in 2000 from the bequest of northern biologist Thomas H. Manning (1911–1998), provides financial assistance for the publication of papers in the CFN by independent (non-institutional) authors, with particular priority given to those addressing arctic and boreal issues. Qualifying authors should make their application for assistance from the Fund at the time of their initial submission.

COVER: The terrestrial snail study area at Constance Bay, Ontario consisting of Northern Red Oak (*Quercus rubra*) – Large-toothed Aspen (*Populus grandidentata*) woods (left) and Red Pine (*Pinus resinosa*) plantation (right). Both habitats were scrub savannah approximately 60 years ago. See the article in this issue by Paul Catling and Brenda Kostiuk, pages 128–132. Photos: Paul Catling, September 2014.

Has the Eastern Red-backed Salamander (*Plethodon cinereus*) Declined in Ontario?

DAVID C. SEBURN^{1,3} and ERIN MALLON²

¹Seburn Ecological Services, 2710 Clarendon Street, Ottawa, Ontario K2B 7S5 Canada

²Ontario Nature, Suite 612, 214 King Street West, Toronto, Ontario M5H 3S6 Canada

³Corresponding author: davidseburn@sympatico.ca

Seburn, David C., and Erin Mallon. 2017. Has the Eastern Red-backed Salamander (*Plethodon cinereus*) declined in Ontario? Canadian Field-Naturalist 131(2): 115–119. <https://doi.org/10.22621/cfn.v131i2.1981>

Amphibians are known to be declining around the world. Although often only reported for frogs, declines among salamanders are also known to be occurring. In Ontario, for example, citizen science monitoring indicates the Eastern Red-backed Salamander (*Plethodon cinereus*) has not been found in the last 20 years in many areas where it was historically known to occur. To test whether this decline is real or the result of lack of recent observations, we conducted targeted surveys in 25 grid squares with no recent records of the species and confirmed the presence of the Eastern Red-backed Salamander in 84% of these squares. It made up 90% (183 of 202) of all six species of salamanders encountered and was also the first salamander species detected in 90% of the squares. The median number of cover objects needed to detect a species was 34 (range 1–145) for Eastern Red-backed Salamanders, 129.5 (range 34–204) for Blue-spotted Salamanders (*Ambystoma laterale*), and 154 (range 6–187) for Spotted Salamanders (*Ambystoma maculatum*), and these detection rates differed significantly ($H = 9.46$, $P < 0.01$). Our study suggests that Eastern Red-backed Salamanders have not declined. We caution researchers using citizen science data that a lack of sightings of a “cryptic species” does not mean a species has declined.

Key Words: Eastern Red-backed Salamander; *Plethodon cinereus*; amphibian decline; Ontario

Introduction

Amphibian populations are known to be declining around the world (Wake and Vrendenburg 2008; Collins and Crump 2009; Collins 2010), and a global assessment of all known amphibian species concluded that a third were threatened with extinction (Stuart *et al.* 2004). Although amphibian declines are often associated only with frogs, salamanders are also declining with at least two apparent extinctions (Rovito *et al.* 2009). Salamander declines have been reported in Europe (van der Sluijs *et al.* 2013), Central America (Rovito *et al.* 2009), and North America (Bank *et al.* 2006; Means and Travis 2007). Declines have been observed in both aquatic (Wheeler *et al.* 2003; Lowe 2012) and terrestrial salamanders (Maerz *et al.* 2009; Caruso and Lips 2013). Some species have even declined within protected areas where habitat loss has not been an issue (Bank *et al.* 2006). The cause of many of these declines remains uncertain, although newly emerging diseases (Bosch and Martínez-Solano 2006; Martel *et al.* 2014), pollution (Bank *et al.* 2006), invasive species (Maerz *et al.* 2009), habitat loss (Arntzen 2015), and climate change (Parra-Olea *et al.* 2005; Caruso *et al.* 2014) or some combination of factors are all probable.

Salamander declines are important because these amphibians are a critical component of forest ecosystems. For example, the biomass of woodland salamanders is substantial and in some areas can be greater than

that of birds or small mammals (Burton and Likens 1975). Salamanders are significant predators of forest floor invertebrates, and their loss from forest ecosystems could alter invertebrate diversity and soil dynamics as well as carbon and nutrient cycling (Davie and Welsh 2004; Best and Welsh 2014), although not all salamander removal experiments have detected significant changes (e.g., Hocking and Babbitt 2014).

The Ontario Reptile and Amphibian Atlas (ORAA; Ontario Nature 2016) is documenting the current distribution of amphibians and reptiles across Ontario, using 10-km by 10-km grid squares, modeled after the provincial Breeding Bird Atlas (Cadman *et al.* 2008). The ORAA is a citizen science project that relies on volunteer observers, researchers, and land managers to report sightings. Currently, over 3000 people have contributed over 350 000 records. The atlas database builds on the Ontario Herpetofaunal Summary (Oldham and Weller 1989), started in 1984, which includes historical records from published literature, unpublished government reports, and museum records. The overall goal of the ORAA is to document occurrences of herpetofauna across Ontario and identify trends in distribution.

Data from the ORAA suggest that salamanders have declined significantly. For example, there are no recent records (defined as the last 20 years) of the Eastern Red-backed Salamander (*Plethodon cinereus*) from over 400 grid squares where it was historically known to occur.

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalists' Club.

Such absences could indicate that this species has been extirpated from more than 40 000 km². To assess whether the apparent decline is real or a result of lack of observations, we conducted targeted surveys of salamanders in 25 grid squares that lacked recent reports of Eastern Red-backed Salamanders. Although there are similar trends for other woodland salamanders, we selected the Eastern Red-back Salamander as the target species as it is typically more common, often accounting for more than 90% of individuals in salamander surveys in northeastern North America (Degraaf and Yamasaki 1992; Moore 2005; Pearce and Venier 2009).

Methods

We selected a study area west of Ottawa and north of Peterborough because a large number of ORAA grid squares in this region lacked recent reports of salamanders and also contained numerous parcels of easily accessible public land. Within this area, we identified grid squares with historical records from the ORAA (before 1995) of the Eastern Red-backed Salamander, but with no recent records (from 1995 onward). Historical records included citizen science observations, records obtained by the ORAA from published papers, government reports, and museum records. For each grid square with a historical record, we determined whether it contained accessible public land (provincial parks or Crown land). The presence of public land was determined by using Google Maps (2015) for provincial parks and the Ontario government's Crown Land Use Policy Atlas (MNR n.d.) for Crown land. For each square containing public land, we determined the last year of observation for all other woodland salamander species. Priority was given to squares with multiple species of salamanders but only historical records, but an effort was also made to include squares from across the region.

We drove along roads adjacent to (or on) public land to select sites with suitable habitat for woodland salamanders (predominantly deciduous or mixed woods). Selected sites were surveyed in a standardized manner to ensure consistency of results. The two authors, both experienced field biologists, searched under appropriate cover objects (woody debris such as branches, small logs, bark, and anthropogenic debris, such as boards or sheet metal) for 1 h (two person-hours). Cover objects were carefully replaced as accurately as possible to minimize disturbance to the microhabitat. Surveys were stopped before 1 h elapsed if all historically reported salamander species had been detected.

We recorded the number of cover objects searched in each square, the number of cover objects searched to first detect each species, as well as the number of individuals of each species. The location (determined using a handheld Global Positioning System unit), date, time, and weather conditions were recorded for each survey. At four sites, only one biologist (D.C.S.) conducted the surveys and, in these cases, the survey was conducted over 2 h to compensate for the reduction in surveyors.

Some Blue-spotted Salamanders (*Ambystoma laterale*) encountered in this study may have been unisexual polyploids. Given that polyploids must co-occur with Blue-spotted Salamanders, the presence of apparent Blue-spotted Salamanders is evidence that the species occurs at the site (Bogart and Klemens 2008). The median number of salamanders per square includes only squares with full, 1-h surveys and does not include squares where the species was not detected. We did not include squares where the Eastern Red-backed Salamander was not detected because it is possible it was not present. Our interest was in how many cover objects must be searched, on average, to detect each species when it is known to be present.

The non-parametric Kruskal-Wallis test was used for statistical comparisons using Minitab 8.3 (Minitab Inc., State College, Pennsylvania, USA). QGIS 2.0 (QGIS 2017) was used for data mapping.

Results

From 15 July to 18 September 2015, we surveyed 25 grid squares that lacked recent records of the Eastern Red-backed Salamander: 12 within provincial parks and 13 on Crown land. All but three squares were surveyed from 11 to 18 September. Substantial rainfall occurred on the weekend of 12–13 September and soils under cover objects were damp to wet for the following week when most of our surveys were undertaken. Eastern Red-backed Salamanders were detected in 21 of the 25 squares (Figure 1). The four squares where Eastern Red-backed Salamanders were not detected were not spatially clustered. Five other species of salamanders were detected in seven or fewer squares (Table 1). The median number of species detected in squares where full surveys were conducted was two (range 0–3, $n = 17$). Although the other salamander species were detected in few grid squares, at least 50% of the species detections resulted in the first recent report of the species in the square (Table 1).

There was no significant difference between the date of the last historical observation of Eastern Red-backed Salamanders in squares where we detected them (median date 1988, range 1977–1994) and squares where we did not detect them (median date 1987, range 1984–1993; $H = 0.01$, $P > 0.9$).

Eastern Red-backed Salamanders made up 90% (183 of 202) of all salamanders encountered. Considering the three most common species, the median number of individuals per square was eight for Eastern Red-backed Salamanders (range 2–37, $n = 13$), one for Blue-spotted Salamanders (range 1–2, $n = 3$), and one for Spotted Salamanders (*Ambystoma maculatum*; range 1–1, $n = 6$).

We surveyed 3876 cover objects in the 25 grid squares. A median of 205 (range 148–272) cover objects were checked per square when full surveys were conducted. Eastern Red-backed Salamander was the first species detected in 90% (19 of 21 squares) of the squares where they were found. For species found in

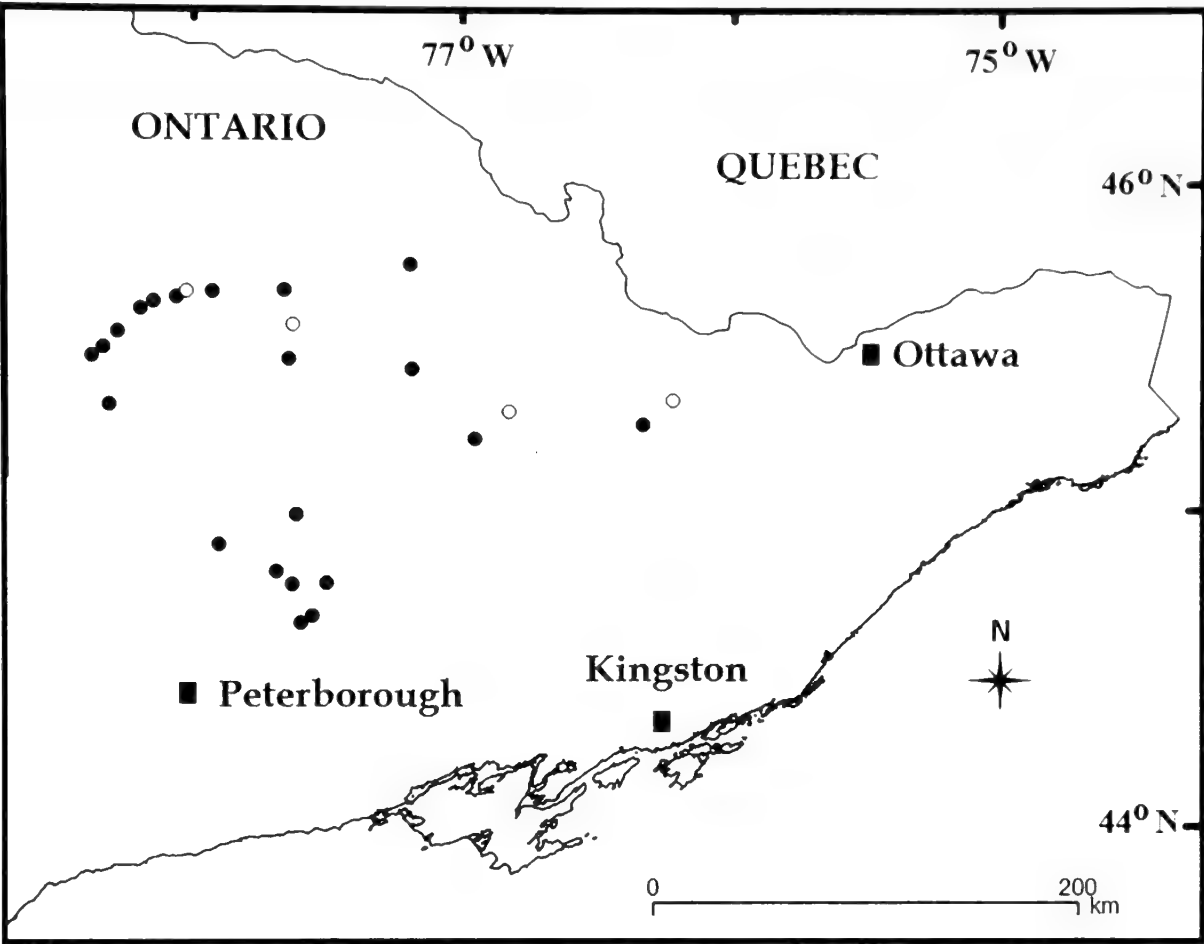


Figure 1. Location of salamander survey sites in Ontario. Solid circles indicate sites where Eastern Red-backed Salamander (*Plethodon cinereus*) was detected and open circles indicate where the species was not detected.

TABLE 1. Salamanders detected during surveys in 25 grid squares (10-km × 10-km) in Ontario in 2015. Squares with first recent record indicates the number of squares where this observation was the first recent (last 20 years) report of the species.

Species	Detected, no. squares	First recent record, no. squares (%)	No. found	Maximum no./square
LUNGLESS SALAMANDERS				
Red-backed Salamander (<i>Plethodon cinereus</i>)	21	21 (100)	183	37
Four-toed Salamander (<i>Hemidactylum scutatum</i>)	1	1 (100)	1	1
Northern Two-lined Salamander (<i>Eurycea bislineata</i>)	2	1 (50)	4	3
MOLE SALAMANDERS				
Blue-spotted Salamander (<i>Ambystoma laterale</i>)	4	2 (50)	5	2
Spotted Salamander (<i>Ambystoma maculatum</i>)	7	5 (71)	7	1
NEWTS				
Eastern Newt (<i>Notophthalmus viridescens</i>)	2	2 (100)	2	1

four or more squares, the median number of cover objects checked to detect a species was 34 for Eastern Red-backed Salamanders (range 1–145, $n = 21$), 129.5 for Blue-spotted Salamanders (range 34–204, $n = 4$), and 154 for Spotted Salamanders (range 6–187, $n = 7$), and these detection rates were significantly different ($H = 9.46$, $P < 0.01$).

Discussion

The Eastern Red-backed Salamander was easily detected in 84% of the squares we surveyed. A longer survey might have detected Eastern Red-backed Salamanders in more squares; however, detection probability for this species under natural cover objects reaches approximately 100% after 45 minutes (Otto and Roloff 2011).

Given that each grid square is 100 km² and that we surveyed only one small site for two person-hours, it is likely that, if we had surveyed multiple sites per grid square, we would have detected Eastern Red-backed Salamanders in an even greater percentage of squares. Thus, there appears to be no evidence that this species has been eliminated from parts of our study area. However, it is possible that the Eastern Red-backed Salamander has declined in other parts of the province as salamanders were rarely encountered in systematic amphibian surveys in southern Ontario, possibly because of widespread loss of forest cover (Hecnar 1997).

Eastern Red-backed Salamander made up 90% of the salamanders detected in this study. Other studies in Canada or the northern United States have found that Eastern Red-backed Salamanders make up at least 81% of the salamanders encountered (Bonin and Bachand 1997) and usually 90–99% of all salamanders (Degraaf and Yamasaki 1992; Moore 2005; Pearce and Venier 2009).

Eastern Red-backed Salamanders were easily detected in most grid squares, sometimes under the first cover object searched. Although salamanders are easy to find in the appropriate habitat, they are not often reported to the ORAA, where they make up only 2.5% of all amphibian and reptile observations in the last 20 years (unpublished data from the ORAA). Similarly, salamanders account for only 11% of observations contributed to the Carolina Herp Atlas and the low percentage was partially attributed to the cryptic nature of the species (Price and Dorcas 2011). Unlike most other amphibians and reptiles, salamanders are rarely encountered when not actively sought.

Citizen science has been widely demonstrated to be valuable in ecological science (e.g., Delaney *et al.* 2008; Dickinson *et al.* 2010; Ries and Oberhauser 2015). Nonetheless, it has limitations. Volunteers can overlook low-density patches of invasive species (Fitzpatrick *et al.* 2009), and the same may also be true for low-density or cryptic native species. Our results imply that many volunteers may have little interest in actively searching for salamanders. This is supported by the fact that we confirmed the presence of Eastern Red-backed Salamanders in 11 of the 12 squares surveyed within provincial parks, in easily accessible areas, usually along major hiking trails.

Although data from the ORAA are valuable in demonstrating where salamanders are known to occur, a lack of recent reports should not be assumed to indicate a current absence of the species without additional survey effort. Volunteers should be encouraged to visit squares with historical records and survey for salamanders to provide a more complete understanding of the current distribution in Ontario given the global concern over salamander declines. Our results suggest that at least 30 cover objects must be searched under to achieve a 50% probability of detecting Eastern Red-backed Salamanders at a site with suitable habitat, although more than 150 objects need to be checked to have a

50% chance of detecting some other species of woodland salamanders. We encourage individuals surveying for salamanders to record the number of cover objects checked to provide a measure of survey effort. Recording other data such as weather conditions, soil moisture under cover objects (e.g., wet versus dry), and forest type are also valuable. Great care should always be taken to replace cover objects. We also caution researchers using citizen science data that lack of records of a “cryptic species” does not mean a species has declined.

Acknowledgements

This research was funded by the Ontario Wildlife Foundation and the Research Fund of the Ottawa Field-Naturalists' Club. Valuable support was provided by Tanya Pulfer and Mackenzie Nichols of Ontario Nature. We are deeply grateful to everyone who contributed salamander observations to the Ontario Herpetofaunal Summary and the Ontario Reptile and Amphibian Atlas.

Literature Cited

- Arntzen, J. W. 2015. Drastic population size change in two populations of the Golden-Striped Salamander over a forty-year period — are Eucalypt plantations to blame? *Diversity* 7: 270–294. <https://doi.org/10.3390/d7030270>
- Bank, M. S., J. B. Crocker, S. Davis, D. K. Brotherton, R. Cook, J. Behler, and B. Connery. 2006. Population decline of northern dusky salamanders at Acadia National Park, Maine, USA. *Biological Conservation* 130: 230–238. <https://doi.org/10.1016/j.biocon.2005.12.033>
- Best, M. L., and H. H. Welsh, Jr. 2014. The trophic role of a forest salamander: impacts on invertebrates, leaf litter retention, and the humification process. *Ecosphere* 5: 16. <https://doi.org/10.1890/ES13-00302.1>
- Bogart, J. P., and M. W. Klemens. 2008. Additional distributional records of *Ambystoma laterale*, *A. jeffersonianum* (Amphibia: Caudata) and their unisexual kleptogens in northeastern North America. *American Museum Novitates* 3627: 1–58. <https://doi.org/10.1206/604.1>
- Bonin, J., and Y. Bachand. 1997. The use of artificial covers to survey terrestrial salamanders in Québec. Pages 175–179 in *Amphibians in Decline: Canadian Studies of a Global Problem*. Edited by D. M. Green. Herpetological Conservation, volume 1. Society for the Study of Amphibians and Reptiles, St. Louis, Missouri, USA.
- Bosch, J., and I. Martínez-Solano. 2006. Chytrid fungus infection related to unusual mortalities of *Salamandra salamandra* and *Bufo bufo* in the Penalara Natural Park, Spain. *Oryx* 40: 84–89. <https://doi.org/10.1017/S0030605306000093>
- Burton, T. M., and G. E. Likens. 1975. Salamander populations and biomass in the Hubbard Brook Experimental Forest, New Hampshire. *Copeia* 1975: 541–546. <https://doi.org/10.2307/1443655>
- Cadman, M. D., D. A. Sutherland, G. G. Beck, D. Lepage, and A. R. Couturier. 2007. Atlas of Breeding Birds of Ontario 2001–2005. Bird Studies Canada, Environment Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources, and Ontario Nature, Toronto, Ontario, Canada.
- Caruso, N. M., and K. R. Lips. 2013. Truly enigmatic declines in terrestrial salamander populations in Great Smoky

- Mountains National Park. Diversity and Distributions 19: 38–48. <https://doi.org/10.1111/j.1472-4642.2012.00938.x>
- Caruso, N. M., M. W. Sears, D. C. Adams, and K. R. Lips.** 2014. Widespread rapid reductions in body size of adult salamanders in response to climate change. *Global Change Biology* 20: 1751–1759. <https://doi.org/10.1111/gcb.12550>
- Collins, J. P.** 2010. Amphibian decline and extinction: what we know and what we need to learn. *Diseases of Aquatic Organisms* 92: 93–99. <https://doi.org/10.3354/dao02307>
- Collins, J. P., and M. L. Crump.** 2009. Extinction in Our Time: Global Amphibian Decline. Oxford University Press, Oxford, United Kingdom.
- Davie, R. D., and H. H. Welsh.** 2004. On the ecological roles of salamanders. *Annual Review of Ecology, Evolution, and Systematics* 35: 405–434. <https://doi.org/10.1146/annurev.ecolsys.35.112202.130116>
- Degraaf, R. M., and M. Yamasaki.** 1992. A nondestructive technique to monitor the relative abundance of terrestrial salamanders. *Wildlife Society Bulletin* 20: 260–264.
- Delaney, D. G., C. D. Sperling, C. S. Adams, and B. Leung.** 2008. Marine invasive species: validation of citizen science and implications for national monitoring networks. *Biological Invasions* 10: 117–128. <https://doi.org/10.1007/s10530-007-9114-0>
- Dickinson, J. L., B. Zuckerberg, and D. N. Bontar.** 2010. Citizen science as an ecological research tool: challenges and benefits. *Annual Review of Ecology, Evolution, and Systematics* 41: 149–172. <https://doi.org/10.1146/annurev.ecolsys.102209.144636>
- Fitzpatrick, M. C., E. L. Preisser, A. M. Ellison, and J. S. Elkinton.** 2009. Observer bias and the detection of low-density populations. *Ecological Applications* 19: 1673–1679. <https://doi.org/10.1890/09-0265.1>
- Google Maps.** 2015. Map of Ontario showing provincial parks [online]. Google. Accessed July–September 2015. <https://www.google.ca/maps>.
- Hecnar, S. J.** 1997. Amphibian pond communities in southwestern Ontario. Pages 1–15 in *Amphibians in Decline: Canadian Studies of a Global Problem*. Edited by D. M. Green. Herpetological Conservation, volume 1. Society for the Study of Amphibians and Reptiles, St. Louis, Missouri, USA.
- Hocking, D. J., and K. J. Babbitt.** 2014. Effects of red-backed salamanders on ecosystem functions. *PloS One* 9: e86854. <https://doi.org/10.1371/journal.pone.0086854>
- Lowe, W. H.** 2012. Climate change is linked to long-term decline in a stream salamander. *Biological Conservation* 145: 48–53. <https://doi.org/10.1016/j.biocon.2011.10.004>
- Martel, A., M. Blooi, C. Adriaensen, P. Van Rooij, W. Beukema, M. C. Fisher, R. A. Farrer, B. R. Schmidt, U. Tobler, K. Goka, K. R. Lips, C. Mulet, K. R. Zamudio, J. Bosch, S. Lötters, E. Wombwell, T. W. J. Garner, A. A. Cunningham, A. Spitzen-van der Sluijs, S. Salvidio, R. Ducatelle, K. Nishikawa, T. T. Nguyen, J. E. Kolby, I. Van Bocxlaer, F. Bossuyt, and F. Pasmans.** 2014. Recent introduction of a chytrid fungus endangers western Palearctic salamanders. *Science* 346: 630–631. <https://doi.org/10.1126/science.1258268>
- Maerz, J. C., V. A. Nuzzo, and B. Blossey.** 2009. Declines in woodland salamander abundance associated with non-native earthworm and plant invasions. *Conservation Biology* 23: 975–981. <https://doi.org/10.1111/j.1523-1739.2009.01167.x>
- Means, D. B., and J. Travis.** 2007. Declines in ravine-inhabiting dusky salamanders of the southeastern US coastal plain. *Southeastern Naturalist* 6: 83–96. [https://doi.org/10.1656/1528-7092\(2007\)6\[83:DIRDSO\]2.0.CO;2](https://doi.org/10.1656/1528-7092(2007)6[83:DIRDSO]2.0.CO;2)
- MNRF (Ministry of Natural Resources and Forestry).** n.d. Crown land use policy atlas. MNRF, Toronto, Ontario, Canada. Accessed July–Sept 2015. <http://www.gisapphication.lrc.gov.on.ca/CLUPA/Index.html?site=CLUPA&viewer=CLUPA&locale=en-US>
- Moore, J.-D.** 2005. Use of native dominant wood as a new coverboard type for monitoring Eastern Red-backed Salamanders. *Herpetological Review* 36: 268–271.
- Oldham, M. J., and W. F. Weller.** 1989. Ontario Herpetofaunal Summary, 1986. Ontario Field Herpetologists, Cambridge, Ontario, Canada.
- Otto, C. R. V., and G. J. Roloff.** 2011. Comparing cover object and leaf litter surveys for detecting Red-Backed Salamanders, *Plethodon cinereus*. *Journal of Herpetology* 45: 256–260. <https://doi.org/10.1670/10-039.1>
- Parra-Olea, G., E. Martínez-Meyer, and G. P. P. De León.** 2005. Forecasting climate change effects on salamander distribution in the highlands of central Mexico. *Biotropica* 37: 202–208. <https://doi.org/10.1111/j.1744-7429.2005.00027.x>
- Pearce, J., and L. Venier.** 2009. Are salamanders good bio-indicators of sustainable forest management in boreal forests? *Canadian Journal of Forest Research* 39: 169–179. <https://doi.org/10.1139/X08-169>
- Price, S. J., and M. E. Dorcas.** 2011. The Carolina Herp Atlas: an online, citizen-science approach to document amphibian and reptile occurrences. *Herpetological Conservation and Biology* 6: 287–296.
- QGIS.** 2017. A free and open source geographic information system. Accessed 18 June 2017. <http://www.qgis.org/en/site>.
- Ries, L., and K. Oberhauser.** 2015. A citizen army for science: quantifying the contributions of citizen scientists to our understanding of Monarch Butterfly biology. *BioScience* 65: 419–430. <https://doi.org/10.1093/biosci/bix011>
- Rovito, S. M., G. Parra-Olea, C. R. Vásquez-Almazán, T. J. Papenfuss, and D. B. Wake.** 2009. Dramatic declines in neotropical salamander populations are an important part of the global amphibian crisis. *Proceedings of the National Academy of Sciences* 106: 3231–3236. <https://doi.org/10.1073/pnas.0813051106>
- Stuart, S., J. S. Chanson, N. A. Cox, B. E. Young, A. S. L. Rodrigues, D. L. Fishman, and R. W. Waller.** 2004. Status and trends of amphibian declines and extinctions worldwide. *Science* 306: 1783–1786. <https://doi.org/10.1126/science.1103538>
- van der Sluijs, A. M., F. Spikmans, W. Bosman, M. de Zeeuw, T. van der Meij, E. Goverse, M. Kik, F. Pasmans, and A. Martel.** 2013. Rapid enigmatic decline drives the fire salamander (*Salmandra salamandra*) to the edge of extinction in the Netherlands. *Amphibia-Reptilia* 34: 233–239. <https://doi.org/10.1163/15685381-00002891>
- Wake, D. B., and V. T. Vredenburg.** 2008. Are we in the midst of the sixth mass extinction? A view from the world of amphibians. *Proceedings of the National Academy of Sciences* 105: 11466–11473. <https://doi.org/10.1073/pnas.0801921105>
- Wheeler, B. A., E. Prosen, A. Mathis, and R. F. Wilkinson.** 2003. Population declines of a long-lived salamander: a 20-year study of hellbenders, *Cryptobranchus alleganiensis*. *Biological Conservation* 109: 151–156. [https://doi.org/10.1016/S0006-3207\(02\)00136-2](https://doi.org/10.1016/S0006-3207(02)00136-2)

Received 7 February 2016

Accepted 10 May 2017

Note

Marine Mammal and Sea Turtle Sightings During a Survey of the Endeavour Segment of the Juan de Fuca Ridge, British Columbia

MEIKE HOLST

LGL Limited, environmental research associates, 9768 Second Street, Sidney, British Columbia V8L 3Y8 Canada; email: mholst@lgl.com

Holst, Meike. 2017. Marine mammal and sea turtle sightings during a survey of the Endeavour Segment of the Juan de Fuca Ridge, British Columbia. *Canadian Field-Naturalist* 131(2): 120–124. <https://doi.org/10.22621/cfn.v131i2.1873>

Marine mammals and sea turtles were documented as part of a monitoring and mitigation program during a seismic study offshore (~250 km) from Vancouver Island, British Columbia, during August–September 2009. Forty-one marine mammals in nine groups were sighted. Dall's Porpoise (*Phocoenoides dalli*) was the most frequently sighted species. A Sperm Whale (*Physeter macrocephalus*), a pod of Pacific White-sided Dolphins (*Lagenorhynchus obliquidens*), an unidentified toothed whale, a Northern Elephant Seal (*Mirounga angustirostris*), and a Leatherback Turtle (*Dermochelys coriacea*) were also observed. These data augment current knowledge on the occurrence of marine mammals and sea turtles in the offshore waters of British Columbia.

Key Words: Dall's Porpoise; *Phocoenoides dalli*; Leatherback Turtle; *Dermochelys coriacea*; Northern Elephant Seal; *Mirounga angustirostris*; Sperm Whale; *Physeter macrocephalus*; Pacific White-sided Dolphins; *Lagenorhynchus obliquidens*; seismic survey; marine mammal; Vancouver Island; British Columbia; Endeavour Hydrothermal Vent Marine Protected Area

Introduction

Limited information is available on the occurrence and distribution of marine mammals and sea turtles inhabiting the offshore waters of British Columbia. Although marine mammal surveys have taken place in deep offshore waters out to the edge of the exclusive economic zone approximately 200 nautical miles off the coast of Washington (e.g., Barlow and Forney 2007; Barlow 2016), surveys have generally not occurred that far offshore in Pacific waters of Canada. Surveys by Fisheries and Oceans Canada off British Columbia have typically occurred within 50 km of the shelf break and did not extend more than 150 km offshore (Ford *et al.* 2010); the most frequently sighted species were Humpback Whale (*Megaptera novaeangliae*), Fin Whale (*Balaenoptera physalus*), Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*), and Dall's Porpoise (*Phocoenoides dalli*). In addition, systematic surveys have taken place in inshore coastal waters (e.g., Williams and Thomas 2007; Best *et al.* 2015). Opportunistic sightings in offshore waters have also been reported to the British Columbia Cetacean Sightings Network (BCCSN), but these records are not corrected for effort.

As part of the marine mammal monitoring and mitigation program for Lamont-Doherty Earth Observatory's Endeavour Tomography (ETOMO) experiment, biologists watched for marine mammals and sea turtles in and adjacent to the Endeavour Hydrothermal Vent Marine Protected Area (EHV MPA) during an academic seismic survey in August–September 2009. The EHV MPA is a unique ecosystem consisting of hydrothermal vents and associated fauna located ~250 km southwest of Vancouver Island, British Columbia. It covers ~93 km² and lies in water ~2250 m deep. The increased con-

centration of vent-derived material in the EHV MPA is likely enhancing the abundance of zooplankton there, leading, in turn, to increased productivity throughout the entire water column above the venting region (Tunnicliffe and Thomson 1999). However, it is uncertain whether this translates into higher densities of marine mammals and sea turtles above the vent fields (Gisiner *et al.* 2009; Soule *et al.* 2009).

This study was not designed as a systematic marine mammal and sea turtle survey, but rather as part of a program to reduce the possible effects of seismic survey operations on marine animals. Nonetheless, it allowed for determination of encounter rates and contributes to our understanding of the occurrence and distribution of cetaceans, pinnipeds, and turtles in deep, offshore waters of British Columbia.

Methods

The ETOMO experiment took place in and around the EHV MPA, located ~250 km southwest of Vancouver Island, British Columbia, within the area bounded by 47°–49°N and 127°30'–130°W (Figure 1). The seismic vessel *Marcus G. Langseth* left Astoria, Oregon, on 22 August 2009. During the study, a 36-airgun array with a total discharge volume of 6600 in³ (108 155 cm³) was towed behind the *Langseth*. The source array had an acoustic output (downward) of 259 dB re 1 µPa m_{zero-to-peak}. A brief (~0.1 s) pulse of sound was emitted every ~250–500 m along designated transect lines. Airgun operations occurred day and night on a daily basis starting on 26 August and concluding on 11 September. During seismic acquisition, the vessel traveled 7–9 km/h; when not towing gear (e.g., during transits to the study area), the *Langseth* cruised at 20–24 km/h. Water depth in the survey area was > 2000 m.

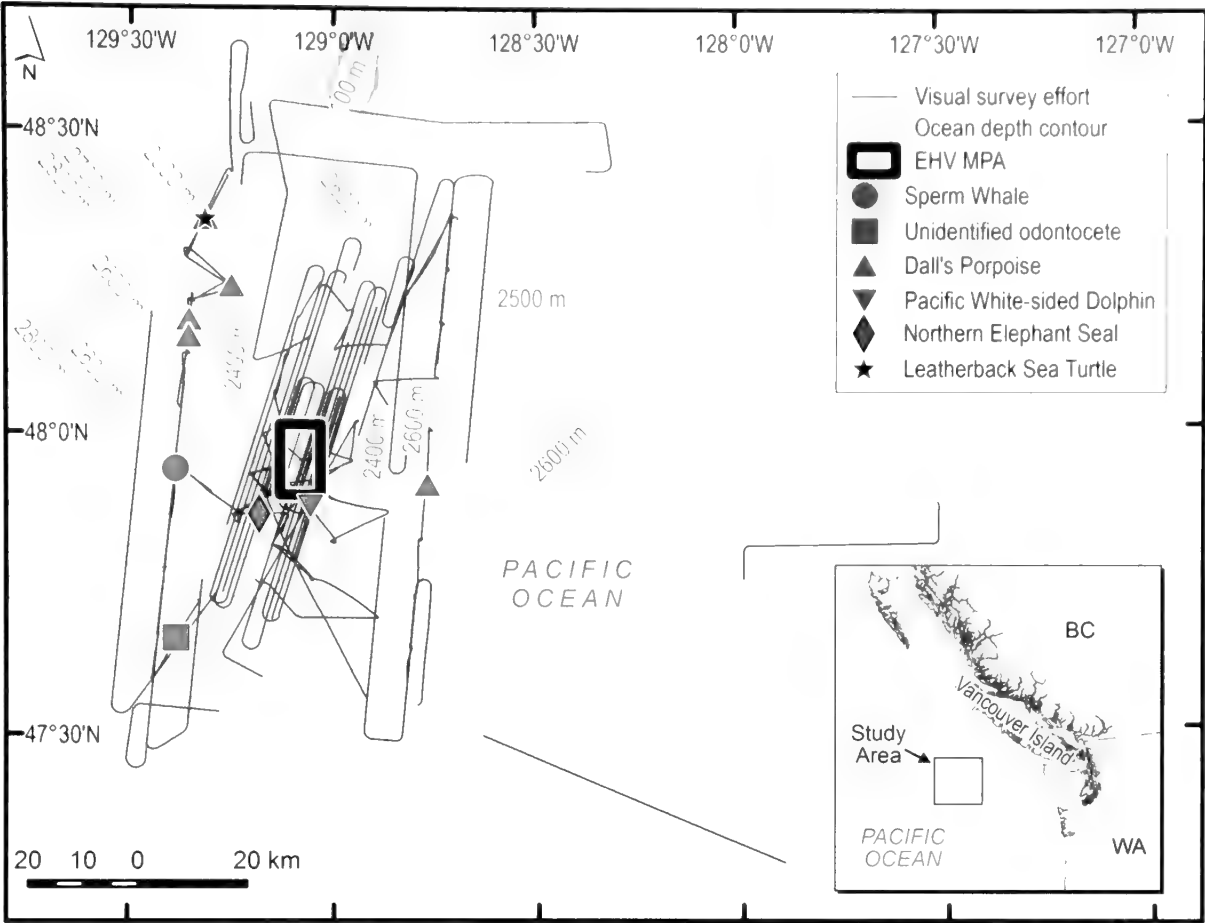


FIGURE 1. The Endeavour Tomography survey area showing observation effort and sightings of marine mammals and a sea turtle, 23 August to 18 September 2009. Note: EHV MPA = Endeavour Hydrothermal Vent Marine Protected Area.

Standard monitoring and mitigation measures were implemented during the study, including ramp-up, power-down, and shut-down procedures (e.g., Nowacek *et al.* 2013; Wright and Cosentino 2015). Visual observations commenced 23 August and continued until 18 September. One or two experienced observers (out of a team of six) watched for marine mammals and sea turtles from approximately 0700 to 2030 from the *Langseth's* observation tower, ~20 m above sea level. Observers were on watch for shifts no longer than 4 h. The observers used 7 × 50 reticle binoculars, 25 × 150 big-eye binoculars, and the naked eye to look for marine mammals and sea turtles around the vessel. While on watch, observers kept written records of environmental conditions and vessel activities every 30 minutes. For each sighting, species, identification reliability, number of individuals, environmental conditions (glare, visibility, Beaufort wind force), date, time, and vessel position and activity were recorded on a datasheet.

Encounter rates (number of sightings per 1000 km surveyed and number of individuals per 1000 km) were determined for all species seen during periods without airgun activity. These “non-seismic” periods included only data collected before or more than 6 h after seismic

operations had ceased; the 6-h period was used to distinguish seismic periods from those periods where seismic surveys were sufficiently far in the past that it could be assumed that they had no residual effect on current animal behaviour or distribution. In addition, only data obtained during Beaufort wind force ≤ 5 and when the vessel travelled at speeds over 3.7 km h were used to determine encounter rates.

Results

The ETOMO experiment included 330 h of observations covering ~2714 km; 121 h of observations (~1036 km) took place during periods when the seismic source was not operating, and the remaining effort occurred when airguns were operational. During non-seismic periods, nearly half of all observations (47%) were made by one observer; the remainder were made by two observers. Although the variable number of observers introduced a source of bias, we did not correct for it. Most observation effort (67%) occurred during Beaufort wind force ≤ 4.

A total of 41 marine mammals in nine groups were sighted; none were seen within the EHV MPA (Figure 1). Dall's Porpoise was the most frequently sighted spe-

cies (five groups totalling 28 individuals); a Sperm Whale (*Physeter macrocephalus*), a pod of ten Pacific White-sided Dolphins, one unidentified odontocete, and one Northern Elephant Seal (*Mirounga angustirostris*) were also observed. In addition, one Leatherback Sea Turtle (*Dermochelys coriacea*) was seen. Except for the pod of Pacific White-sided Dolphins, which was observed on 25 August before seismic operations commenced, all sightings were made during September after all airgun activity had ceased. Thus, all sightings occurred during non-seismic periods. The encounter rate was highest for Dall's Porpoise (5.0 groups/1000 km surveyed or 31.4 individuals/1000 km); the encounter rate for Pacific White-sided Dolphin was 16.5 individuals/1000 km. All other species were encountered at a rate of 1.7 groups/1000 km.

Discussion

Although the ETOMO experiment was designed to obtain information on the sub-seafloor structure of volcanic and hydrothermal features that form as a result of movements of the Earth's tectonic plates, useful information on the occurrence of marine mammals and a sea turtle in the area was also collected. Numerous sightings of Leatherback Turtles have been made throughout the waters of British Columbia, including offshore from Vancouver Island (McAlpine *et al.* 2004; Pacific Leatherback Turtle Recovery Team 2006; Spaven *et al.* 2009). Our sighting on 11 September is one of the farthest offshore observations — if not the farthest — reported for British Columbia. Most other reported sightings have occurred in August, followed by September (Spaven *et al.* 2009). Sightings of Leatherback Turtles have also been made off Washington in 1989 and 1990; most turtles occurred in continental slope waters, although some were found over the shelf (Green *et al.* 1992). During that study, all sightings were reported for June–September, with most in July.

There is a lack of information on the at-sea distribution of Northern Elephant Seals in British Columbia (Best *et al.* 2015). However, Elephant Seals are known to transit through the offshore waters of Vancouver Island, including our study area, as they move between southern rookeries and northern feeding areas (e.g., Le Boeuf *et al.* 2000; Ganong 2012; Robinson *et al.* 2012). Elephant Seals and Northern Fur Seals (*Callorhinus ursinus*) have been seen in the deep offshore waters of British Columbia and Washington (Bonnell *et al.* 1992; Ford 2014). Steller Sea Lions (*Eumetopias jubatus*) have been sighted in coastal waters of British Columbia (Ford 2014) and in shelf and slope waters of Washington (Bonnell *et al.* 1992).

Based on information from sightings in the offshore waters of Washington (e.g., Green *et al.* 1992; Barlow and Forney 2007; Becker *et al.* 2014; Barlow 2016),

Dall's Porpoises, Pacific White-sided Dolphins, Northern Right Whale Dolphins (*Lissodelphis borealis*), and Risso's Dolphins (*Grampus griseus*) were expected to be common in the ETOMO study area. Dall's Porpoise and Pacific White-sided Dolphin have been reported most often in this area, based on opportunistic sightings found in the BCCSN database¹, with more than 25 sightings each, followed by Fin and Humpback Whales with fewer than ten sightings each (BCCSN, unpublished data 1956–2015). The encounter rates (number per 1000 km) for Pacific White-sided Dolphin and Dall's Porpoise derived from the ETOMO study were greater than those for offshore areas of Washington, where 3.2–8.2 and 1.6–4.6/1000 km were found during summer and fall, respectively (Green *et al.* 1992).

In contrast to expectations based on surveys off Washington, only four sightings of Northern Right Whale Dolphins and no Risso's Dolphins were made in the ETOMO study area (BCCSN, unpublished data 1956–2015). Other opportunistic sightings in the ETOMO study area west of 127.5°W include two sightings each of Grey (*Eschrichtius robustus*), Sperm, Killer (*Orcinus orca*), and Short-finned Pilot (*Globicephala macrorhynchus*) Whales; and single sightings of Blue (*Balaenoptera musculus*) and Sei (*B. borealis*) Whales (BCCSN, unpublished data 1956–2015). Short-finned Pilot Whales and Pacific White-sided Dolphins have also been reported in offshore waters of Vancouver Island, including within the ETOMO study area (Stacey and Baird 1991; Baird and Stacey 1993; Ford 2014). Other species reported off the west coast of Vancouver Island within 150 km of shore include Cuvier's Beaked Whale (*Ziphius cavirostris*), Harbour Porpoise (*Phocoena phocoena*), and Risso's Dolphin (Ford *et al.* 2010; Ford 2014).

Our Sperm Whale sighting is one of the farthest offshore sightings made for this area (see Ford 2014); previous sightings occurred east of 128.2°W (BCCSN, unpublished data 1956–2015). Opportunistic sightings of Dall's Porpoise ($n = 6$), Pacific White-sided Dolphin ($n = 4$), Fin Whale ($n = 2$), and Humpback Whale ($n = 1$) have been made within the EHV MPA during June, July, and September (BCCSN, unpublished data 1956–2015). In addition, seismometers deployed near the hydrothermal vent fields from 2003 to 2006 detected Fin and Blue Whale calls every year (Soule *et al.* 2009). Fin and Blue Whale calls had previously been detected by bottom-mounted hydrophones deployed just south of the ETOMO study area (McDonald *et al.* 1995). No sightings were made within the EHV MPA during the ETOMO study, but only 220 km (65 km during non-seismic and 155 km during seismic operations) of the total 2714 km of survey effort occurred within the EHV MPA.

¹Data obtained from the BCCSN were collected opportunistically with limited knowledge of the temporal or spatial distribution of observer effort. As a result, absence of sightings at any location does not demonstrate absence of cetaceans.

As all sightings during the ETOMO study occurred during non-seismic periods, it is possible that marine mammals actively avoided the area around the operating source, thereby reducing encounter rates. Localized and short-term behavioural responses that include movement away from the sound source have been reported for some cetaceans during seismic surveys (e.g., Richardson *et al.* 1995; Gordon *et al.* 2004; Nowacek *et al.* 2007; Southall *et al.* 2007). Despite this limitation, our study allowed for the first effort-corrected sighting data to be collected >150 km off Vancouver Island and contributes to our understanding of marine mammal and sea turtle distribution and occurrence in offshore waters of British Columbia. Given the limited amount of data currently available, it is not possible to assess whether the EHV MPA is a concentration area for marine mammals; additional surveys would need to be undertaken in and around the area.

Acknowledgements

This work was conducted under an Incidental Harassment Authorization issued to Lamont-Doherty Earth Observatory (L-DEO) by the United States National Marine Fisheries Service, Office of Protected Resources, and under permits obtained from Fisheries and Oceans Canada. The survey was funded by L-DEO and the National Science Foundation. L-DEO also provided the logistical support for this cruise and the associated monitoring program. I thank the geophysics team from the University of Oregon, who helped make the cruise a success and the dedicated observers (J. Beland, G. Caltavuturo, K. Graham, B. Dawe, M. Myer, and J. Nicolas). The paper was improved by comments from J. Beland, M. Demarchi, B. Koski, and two anonymous reviewers. M. Fitzgerald provided assistance with data processing and mapping. In addition, I thank the Vancouver Aquarium Marine Science Centre and Fisheries and Oceans Canada for providing sightings from the British Columbia Cetacean Sighting Network's database for offshore Vancouver Island, 1956–2015.

Literature Cited

- Baird, R. W., and P. J. Stacey.** 1993. Sightings, strandings and incidental catches of short-finned pilot whales, *Globicephala macrorhynchus*, off the British Columbia coast. Report of the International Whaling Commission, special issue 14: 475–479.
- Barlow, J.** 2016. Cetacean abundance in the California Current estimated from ship-based line-transect surveys in 1991–2014. Administrative report LJ-12-01. Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, California, USA.
- Barlow, J., and K. A. Forney.** 2007. Abundance and population density of cetaceans in the California Current ecosystem. Fishery Bulletin 105: 509–526.
- Becker, E. A., K. A. Forney, D. G. Foley, R. C. Smith, T. J. Moore, and J. Barlow.** 2014. Predicting seasonal density patterns of California cetaceans based on habitat models. Endangered Species Research 23: 1–22. <https://doi.org/10.3354/esr00548>
- Best, B. D., C. H. Fox, R. Williams, P. N. Halpin, and P. C. Paquet.** 2015. Updated marine mammal distribution and abundance estimates in British Columbia. Journal of Cetacean Research and Management 15: 9–26.
- Bonnell, M. L., C. E. Bowlby, and G. A. Green.** 1992. Pinniped distribution and abundance off Oregon and Washington, 1989–1990. Chapter II in Oregon and Washington Marine Mammal and Seabird Surveys. OCS Study MMS 91-0093. Edited by J. J. Brueggeman. Final report prepared by Ebasco Environmental, Bellevue, Washington, and Ecological Consulting Inc., Portland, Oregon, for U.S. Minerals Management Service, Pacific OCS Region, Los Angeles, California, USA.
- Ford, J. K. B.** 2014. Marine Mammals of British Columbia. Royal British Columbia Museum, Victoria, British Columbia, Canada.
- Ford, J. K. B., R. M. Abernethy, A. V. Phillips, J. Calambokidis, G. M. Ellis, and L. M. Nichol.** 2010. Distribution and relative abundance of cetaceans in western Canadian waters from ship surveys, 2002–2008. Canadian technical report of fisheries and aquatic sciences 2913. Fisheries and Oceans Canada, Science Branch, Pacific Biological Station, Nanaimo, British Columbia, Canada.
- Ganong, J.** 2012. TOPP summary of SSM-derived telemetry. Provided by Census of Marine Life Tagging of Pacific Predators Dataset; downloaded from Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations. Accessed 12 June 2017. <http://www.iobis.org/mapper>.
- Gisiner, R., W. S. D. Wilcock, R. E. Thomson, D. C. Soule, B. R. Mate, C. W. Clark, and M. A. Daher.** 2009. Vents to whales: a possible trophic link between vent communities and large baleen whales. Abstract. Presented at the 18th Biennial Conference on the Biology of Marine Mammals, 12–16 October 2009, Québec, Quebec, Canada. Society for Marine Mammalogy, Anacortes, Washington, USA.
- Gordon, J., D. Gillespie, J. Potter, A. Frantzis, M. P. Simmonds, R. Swift, and D. Thompson.** 2004. A review of the effects of seismic surveys on marine mammals. Marine Technology Society Journal 37: 16–34. <https://doi.org/10.4031/002533203787536998>
- Green, G. A., J. J. Brueggeman, R. A. Grotefendt, C. E. Bowlby, M. L. Bonnell, and K. C. Balcomb, III.** 1992. Cetacean distribution and abundance off Oregon and Washington, 1989–1990. Chapter I in Oregon and Washington Marine Mammal and Seabird Surveys. OCS study MMS 91-0093. Edited by J. J. Brueggeman. Final report prepared by Ebasco Environmental, Bellevue, Washington, and Ecological Consulting Inc., Portland, Oregon, for U.S. Minerals Management Service, Pacific OCS Region, Los Angeles, California, USA.
- Le Boeuf, B. J., D. E. Crocker, D. P. Costa, S. B. Blackwell, P. M. Webb, and D. S. Houser.** 2000. Foraging ecology of northern elephant seals. Ecological Monographs 70: 353–382. [https://doi.org/10.1890/0012-9615\(2000\)070\[0353:FEONES\]2.0.CO;2](https://doi.org/10.1890/0012-9615(2000)070[0353:FEONES]2.0.CO;2)
- McAlpine, D. F., S. A. Orchard, K. A. Sendall, and R. Palm.** 2004. Status of marine turtles in British Columbia waters: a reassessment. Canadian Field-Naturalist 118: 72–76. <https://doi.org/10.22621/cfn.v118i1.885>
- McDonald, M. A., J. A. Hildebrand, and S. C. Webb.** 1995. Blue and fin whales observed on a seafloor array in the Northeast Pacific. Journal of the Acoustical Society of America 98: 712–721. <https://doi.org/10.1121/1.413565>

- Nowacek, D. P., K. Bröker, G. Donovan, G. Gailey, R. Raca, R. R. Reeves, A. I. Vedenev, D. W. Weller, and B. L. Southall.** 2013. Responsible practices for minimizing and monitoring environmental impacts of marine seismic surveys with an emphasis on marine mammals. *Aquatic Mammals* 39: 356–377. <https://doi.org/10.1578/AM.39.4.2013.356>
- Nowacek, D. P., L. H. Thorne, D. W. Johnston, and P. L. Tyack.** 2007. Responses of cetaceans to anthropogenic noise. *Mammal Review* 37: 81–115. <https://doi.org/10.1111/j.1365-2907.2007.00104.x>
- Pacific Leatherback Turtle Recovery Team.** 2006. Recovery strategy for Leatherback Turtles (*Dermochelys coriacea*) in Pacific Canadian waters. Species at Risk Act recovery strategy series. Fisheries and Oceans Canada, Vancouver, British Columbia, Canada.
- Richardson, W. J., C. R. Greene, Jr., C. I. Malme, and D. H. Thomson.** 1995. *Marine Mammals and Noise*. Academic Press, San Diego, California, USA.
- Robinson, P. W., D. P. Costa, D. E. Crocker, J. P. Gallo-Reynoso, C. D. Champagne, M. A. Fowler, C. Goetsch, K. T. Goetz, J. L. Hassrick, L. A. Hückstädt, and C. E. Kuhn.** 2012. Foraging behavior and success of a mesopelagic predator in the Northeast Pacific Ocean: insights from a data-rich species, the northern elephant seal. *PLoS ONE* 7: e36728. <https://doi.org/10.1371/journal.pone.0036728>
- Southall, B. L., A. E. Bowles, W. T. Ellison, J. J. Finneran, R. L. Gentry, C. R. Greene, Jr., D. Kastak, D. R. Ketten, J. H. Miller, P. E. Nachtigall, W. J. Richardson, J. A. Thomas, and P. L. Tyack.** 2007. Marine mammal noise exposure criteria: initial scientific recommendations. *Aquatic Mammals* 33: 411–522. <https://doi.org/10.1121/1.4783461>
- Soule, D. C., W. S. D. Wilcock, and R. E. Thomson.** 2009. Distribution of fin and blue whales above hydrothermal vent fields on the Juan de Fuca Ridge, NE Pacific Ocean. Abstract. Presented at the 18th Biennial Conference on the Biology of Marine Mammals, 12–16 October 2009, Québec, Quebec, Canada. Society for Marine Mammalogy, Anacortes, Washington, USA.
- Spaven, L. D., J. K. B. Ford, and C. Sbrocchi.** 2009. Occurrence of leatherback sea turtles (*Dermochelys coriacea*) off the Pacific coast of Canada, 1931–2009. Canadian technical report of fisheries and aquatic sciences 2858. Fisheries and Oceans Canada, Science Branch, Pacific Biological Station, Nanaimo, British Columbia, Canada.
- Stacey, P. J., and R. W. Baird.** 1991. Status of the Pacific white-sided dolphin, *Lagenorhynchus obliquidens*, in Canada. *Canadian Field-Naturalist* 105: 219–232.
- Tunncliffe, V., and R. Thomson.** 1999. The endeavour hot vents area: a pilot marine protected area in Canada's Pacific Ocean. Background report. Fisheries and Oceans Canada, Sidney, British Columbia, Canada.
- Williams, R., and L. Thomas.** 2007. Distribution and abundance of marine mammals in the coastal waters of British Columbia, Canada. *Journal of Cetacean Research and Management* 9: 15–28.
- Wright, A. J., and A. M. Consentino.** 2015. JNCC guidelines for minimizing the risk of injury and disturbance to marine mammals from seismic surveys: we can do better. *Marine Pollution Bulletin* 100: 231–239. <https://doi.org/10.1016/j.marpolbul.2015.08.045>

Received 7 November 2016

Accepted 9 June 2017

Common Nighthawks (*Chordeiles minor*) Can Take Off from Water

LIAM P. MCGUIRE^{1,3} and R. MARK BRIGHAM²

¹Department of Biological Sciences, Texas Tech University, Lubbock, Texas 79409 USA

²Department of Biology, University of Regina, Regina, Saskatchewan S4S 0A2 Canada

³Corresponding author: liam.mcguire@ttu.edu

McGuire, Liam P., and R. Mark Brigham. 2017. Common Nighthawks (*Chordeiles minor*) can take off from water. *Canadian Field-Naturalist* 131(2): 125–127. <https://doi.org/10.22621/cfn.v131i2.1830>

Common Nighthawks (*Chordeiles minor*) are aerial insectivores that often forage over water, at high speeds, and sometimes at high densities. Foraging nighthawks have regularly been observed flying < 1 m from the surface of water. Under these circumstances, navigation errors or mid-air collisions could result in birds falling into the water, with the risk of drowning. We report two observations of Common Nighthawks that fell into a river and were able to take off from the surface of the water easily without any noticeable detrimental effects.

Key Words: Common Nighthawk; *Chordeiles minor*; foraging behaviour; flight ability

Common Nighthawks (*Chordeiles minor*) forage by capturing insects in flight (Brigham *et al.* 2011). Common Nighthawks are widespread and common over much of North America, but are declining in many parts of their range (Nebel *et al.* 2010) and are currently listed as threatened in Canada (COSEWIC 2007; Species at Risk Public Registry 2016). Habitat is variable across the species' range, including prairies, forests with clearings (including areas recently burned or thinned), rocky terrain, or gravel rooftops in urban areas, all typically including open ground cover for nesting (Brigham 1989; Hagar *et al.* 2004; Brigham *et al.* 2011; G. Foley and A. Sidler, unpublished data).

Crepuscular foraging may occur in any part of the home range in which flying insects are found, but is often associated with aquatic emergent insects over water (Brigham and Fenton 1991; Brigham and Barclay 1995; Ng 2009; Taylor 2009). Foraging frequently occurs close (< 1 m) to the water surface and may involve high densities of birds (Taylor 2009; Brigham *et al.* 2011). At our field site in British Columbia, we regularly observe several hundred birds foraging simultaneously along a short (~300 m long and 50 m wide) stretch of river. We have also observed nighthawks fluttering over water and dipping their bill into the water to drink, as reported elsewhere (Brigham *et al.* 2011).

Given the habit of Common Nighthawks to forage over water, in high-density flocks and at high flight speeds (about 6.5 m/s; Brigham *et al.* 1998), it seems likely that navigation errors or mid-air collisions result in some birds falling into the water. Aside from the obvious risk of drowning, in our work with Common Nighthawks at this site, we have observed that handling birds when hands are moist or wet from river water or sweat results in the loss of many ventral body feathers. Thus, birds falling into the water could be at additional risk of losing body feathers, which may have implications for thermoregulation when they roost on the ground.

R.M.B. has studied Common Nighthawks in British Columbia for 30 years (Brigham 1989). For many projects over that period, Common Nighthawks have been captured in mist nets set across the Okanagan River in s̓x̓w̓ə̓x̓n̓itk̓ Provincial Park (formerly Okanagan Falls Provincial Park) near the town of Okanagan Falls, British Columbia, Canada (49°20'26.59"N, 119°34'48.87"W).

In June 2016, we captured 158 nighthawks over six nights as part of an ongoing research project. For the first time, after capturing more than 1000 nighthawks at this site over the years, we observed two birds (one each on two separate nights) fall into the water. Both birds had been released at the net and landed in the water rather than flying away easily as all other birds had done. One bird immediately flapped its wings and took off from the water. The other bird spread its wings and floated downstream on the surface of the river for 3–4 s, travelling about 4 m before flapping and taking off. Neither bird had any difficulty taking off from the surface of the water, nor did they have any difficulty flying after being in the water. Further, we did not observe any feather loss in these birds.

On both nights when a bird ended up in the water, there was a very high density of birds foraging at the capture site. Exact numbers are difficult to determine, but we conservatively estimate that about 400 individuals were foraging over the river. At this time of year, all birds are adult, ruling out the possibility of inexperienced flight. Although it is unclear why the two birds fell into the water, the high density of birds may have interfered with their ability to fly away from the net, and perhaps they ended up in the water to avoid a mid-air collision with another bird. Regardless of the reason, both birds were able to take off easily from the surface of the water and did not appear to suffer any ill effects. Given the long wings and high aspect ratio of Common Nighthawks (Brigham and Fenton 1991), it is somewhat surprising that the birds were able to thrust themselves into the air from the surface of the

water. However, their low wing loading could make it easier.

To our knowledge, this is the first report of the ability of Common Nighthawks (and only the second bird of the family Caprimulgidae) to take off from the surface of a body of water. With high foraging densities and a habit of foraging very close to the surface of the water, it is perhaps not a rare occurrence for a bird to fall into the water. The situation is likely to be even more pronounced when volant juveniles further increase the density of foraging birds, perhaps with less agility than experienced fliers. Fluttering over water and drinking by dipping the bill into the moving current also adds to the risk of falling into the water. Our observations suggest that there is little risk to birds that fall into the water, as they can easily take off from the surface and fly away unharmed.

Among other Caprimulgids, the only record of being on water is for a Chuck-will's-widow (*Antrostomus carolinensis*). Thayer (1899) reported that one alighted on the surface of water and took off. Birds of North America accounts for other aerial insectivores suggest that Tree Swallows (*Tachycineta bicolor*; Winkler *et al.* 2011), Cliff Swallows (*Petrochelidon pyrrhonota*; Brown *et al.* 2017), Bank Swallows (*Riparia riparia*; Garrison 1999), and Barn Swallows (*Hirundo rustica*; Brown and Brown 1999) all paddle their wings and swim to shore if they fall into water. There is no information for Violet-Green Swallows (*Tachycineta thalassina*; Brown *et al.* 2011). Black Swifts (*Cypseloides niger*; Lowther and Collins 2002) are reported not to swim, but there are no reports for other swifts found in Canada. Thus, taking off from water by nighthawks appears to be unlike the strategy employed by other aerial-feeding insect-eating birds.

Acknowledgements

We are grateful to A. Brigham for assistance in the field, and to G. Foley and A. Sidler (University of Regina) for information about nesting habitat. Funding for this research was provided by Texas Tech University and the Natural Sciences and Engineering Research Council of Canada. All research was approved by the Animal Care and Use Committees at Texas Tech University and the University of Regina and conducted under permits from Environment Canada and the British Columbia Ministry of the Environment.

Literature Cited

- Brigham, R. M.** 1989. Roost and nest sites of Common Nighthawks: are gravel roofs important? *Condor* 91: 722–724. <https://doi.org/10.2307/1368127>
- Brigham, R. M., and R. M. Barclay.** 1995. Prey detection by common nighthawks: does vision impose a constraint? *Ecoscience* 2: 276–279. <https://doi.org/10.1080/11956860.1995.11682294>
- Brigham, R. M., and M. B. Fenton.** 1991. Convergence in foraging strategies by two morphologically and phylogenetically distinct nocturnal aerial insectivores. *Journal of Zoology* 223: 475–489. <https://doi.org/10.1111/j.1469-7998.1991.tb04778.x>
- Brigham, R. M., M. B. Fenton, and H. D. J. N. Aldridge.** 1998. Flight speed of foraging common nighthawks (*Chordeiles minor*): does the measurement technique matter? *American Midland Naturalist* 139: 325–330. doi: [https://doi.org/10.1674/0003-0031\(1998\)139\[0325:FsoFCN\]2.0.CO;2](https://doi.org/10.1674/0003-0031(1998)139[0325:FsoFCN]2.0.CO;2)
- Brigham, R. M., J. Ng, R. G. Poulin, and S. D. Grindal.** 2011. Common Nighthawk (*Chordeiles minor*). In *The Birds of North America*. Edited by P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. <https://doi.org/10.2173/bna.213>
- Brown, C. R., and M. B. Brown.** 1999. Barn Swallow (*Hirundo rustica*). In *The Birds of North America*. Edited by P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. <https://doi.org/10.2173/bna.452>
- Brown, C. R., M. B. Brown, P. Pyle, and M. A. Patten.** 2017. Cliff Swallow (*Petrochelidon pyrrhonota*). In *The Birds of North America*. Edited by P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. Accessed 5 February 2017. <https://birdsna.org/Species-Account/bna/species/cliswa>
- Brown, C. R., A. M. Knott, and E. J. Damrose.** 2011. Violet-green Swallow (*Tachycineta thalassina*). In *The Birds of North America*. Edited by P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. <https://doi.org/10.2173/bna.14>
- COSEWIC (Committee on the Status of Endangered Wildlife in Canada).** 2007. COSEWIC assessment and status report on the Common Nighthawk *Chordeiles minor* in Canada. COSEWIC, Ottawa, Ontario, Canada. Accessed 24 July 2016. http://www.sararegistry.gc.ca/virtual_sara/files/cosewic/sr_chordeiles_minor_e.pdf
- Garrison, B. A.** 1999. Bank Swallow (*Riparia riparia*). In *The Birds of North America*. Edited by P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. <https://doi.org/10.2173/bna.414>
- Hagar, J., S. Howlin, and L. Ganio.** 2004. Short-term response of songbirds to experimental thinning of young Douglas-fir forests in the Oregon Cascades. *Forest Ecology and Management* 199: 333–347. <https://doi.org/10.1016/j.foreco.2004.05.054>
- Lowther, P. E., and C. T. Collins.** 2002. Black Swift (*Cypseloides niger*). In *The Birds of North America*. Edited by P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. <https://doi.org/10.2173/bna.676>
- Nebel, S., A. Mills, J. D. McCracken, and P. D. Taylor.** 2010. Declines of aerial insectivores in North America follow a geographic gradient. Présence d'un gradient géographique dans le déclin des insectivores aériens. *Avian Conservation and Ecology* 5: 1. <https://doi.org/10.5751/ACE-00391-050201>
- Ng, J. W.-M.** 2009. Habitat use and home range characteristics of Common Nighthawks (*Chordeiles minor*) in mixed-grass prairie. M.Sc. thesis, University of Regina, Regina, Saskatchewan, Canada.
- Species at Risk Public Registry.** 2016. Species profile: Common Nighthawk. Species at Risk Public Registry Office, Gatineau, Quebec, Canada. Accessed 24 July 2016. http://www.sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=986
- Taylor, P.** 2009. Late-summer feeding and migration behaviour and numerical trends of Common Nighthawks, *Chordeiles minor*, near Pinawa, Manitoba, 1976–2009. *Canadian*

Field-Naturalist 123: 338–345. <https://doi.org/10.22621/cfn.v123i4.1003>

Thayer, G. H. 1899. The Chuck-will's-widow on shipboard. *Auk* 16: 273–276. <https://doi.org/10.2307/4069463>

Winkler, D. W., K. K. Hallinger, D. R. Ardia, R. J. Robertson, B. J. Stutchbury, and R. R. Cohen. 2011. Tree Swallow (*Tachycineta bicolor*). In *The Birds of North America*. Edited by P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. <https://doi.org/10.2173/bna.11>

Received 25 July 2016

Accepted 24 May 2017

Reduced Diversity and Relative Abundance of Terrestrial Snails in a Red Pine Plantation Compared with a Surrounding Northern Red Oak – Large-toothed Aspen Woods

PAUL M. CATLING^{1,2} and BRENDA KOSTIUK¹

¹170 Sanford Ave., Ottawa, Ontario K2C 0E9 Canada

²Corresponding author: catlingpm@gmail.com

Catling, Paul M., and Brenda Kostiuk. 2017. Reduced diversity and relative abundance of terrestrial snails in a Red Pine plantation compared with a surrounding Northern Red Oak – Large-toothed Aspen woods. *Canadian Field-Naturalist* 131(2): 128–132. <https://doi.org/10.22621/cfn.v131i2.1982>

A Red Pine (*Pinus resinosa* Aiton) plantation and adjacent Northern Red Oak (*Quercus rubra* L.) – Large-toothed Aspen (*Populus grandidentata* Michx.) woods, both of which developed from a savannah scrub beginning approximately 60 years ago, were compared with regard to terrestrial snail diversity and abundance. The comparison involved a 30-minute search of ten 1-m² quadrats at ten sites in each habitat. In the Northern Red Oak – Large-toothed Aspen woodland, 13 species and 661 individuals were recorded, whereas, in the Red Pine plantation, six species and 24 individuals were recorded. In the Northern Red Oak – Large-toothed Aspen woodland, the most characteristic and abundant species was *Novisuccinea ovalis* (Say, 1817), which was present in 74 of the 100 quadrats and was represented by 460 individuals. In the pine plantation, the most common species was *Zonitoides arboreus* (Say, 1816), which was present in 16 quadrats and was represented by 17 individuals. This species was the second most common in the Northern Red Oak – Large-toothed Aspen woodland where 70 individuals were found in 34 quadrats. In both habitats, *Z. arboreus* was associated with downed wood. Other species occurring in more than 15% of quadrats in the Northern Red Oak – Large-toothed Aspen woodland were *Strobilops labyrinthicus* (Say, 1817), *Glyphyalinia indentata* (Say, 1823), and *Euchemotrema fraternum* (Say, 1824). Although a lower number and diversity of terrestrial snails in the conifer plantation was expected, the contrast was greater than anticipated. The estimated abundance of 46 000 *N. ovalis* per hectare suggests the potential importance of these medium-sized snails in the relatively dry Northern Red Oak – Large-toothed Aspen ecosystem.

Key Words: Terrestrial snails; land snails; *Novisuccinea ovalis*; *Zonitoides arboreus*; savannah; oak woodland; pine plantation; diversity; abundance; Constance Bay; Ontario

Introduction

At Constance Bay, Ontario, an open scrubby savannah of unusual composition (Catling and Brunton 2010; Catling *et al.* 2010) and with rare species followed two different succession paths. Some of it became a dry Northern Red Oak (*Quercus rubra* L.) – Large-toothed Aspen (*Populus grandidentata* Michx.) woodland (Figure 1a), a natural succession favoured in the case of fire suppression. The other path has been the unnatural conversion of the savannah to Red Pine (*Pinus resinosa* Aiton) plantation (Figure 1b), beginning with extensive planting of that species in the 1950s (Catling and Brunton 2010; Catling and Kostiuk 2010; Catling *et al.* 2010). The negative impact of pine plantations on biodiversity in native habitats has been studied in Canada for some groups of organisms, such as vascular plants and grasshoppers (Catling and Kostiuk 2010, 2015). Experimental removal of planted pine trees and pine needle litter at Constance Bay has successfully restored a portion of the savannah (Catling and Kostiuk 2010). Such restorations should be based on data concerning benefits to flora and fauna (Catling and Kostiuk 2010; Spitale 2011; Catling 2013).

The objective here was to determine the impact of plantation on terrestrial snails, by exploring the difference in snail assemblages in the two succession types

after about 60 years. An added benefit is a contribution to better understanding of snail ecology and, particularly, the importance of snails in relatively dry ecosystems.

Study Area

The study area included lands in and near (within 1 km) the Constance and Buckham's Bay Community Centre (45.49944°N, 76.09325°W). The plantation was a pure stand of Red Pine without understory vascular plants but sometimes with a carpet of bryophytes. The Northern Red Oak – Large-toothed Aspen area included old, spreading Northern Red Oaks, as well as young oaks and young aspens; occasional dying Jack Pine (*Pinus banksiana* Lambert); persisting depauperate shrubs from an earlier period of more open conditions, including Early Lowbush Blueberry (*Vaccinium angustifolium* Aiton), Susquehana Sand Cherry (*Prunus susquehanae* Willdenow), Sweet-fern (*Comptonia peregrina* (L.) J. M. Coulter), Black Huckleberry (*Gaylussacia baccata* (Wangeheim) K. Koch), and Poison Ivy (*Toxicodendron radicans* (L.) Kuntz); herbs including Bracken Fern (*Pteridium aquilinum* (L.) K. Kuhn); and graminoids such as Canada Bluegrass (*Poa compressa* L.), Kentucky Bluegrass (*Poa pratensis* L.), and Dry-spike Sedge (*Carex siccata* Dewey).

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalists' Club.

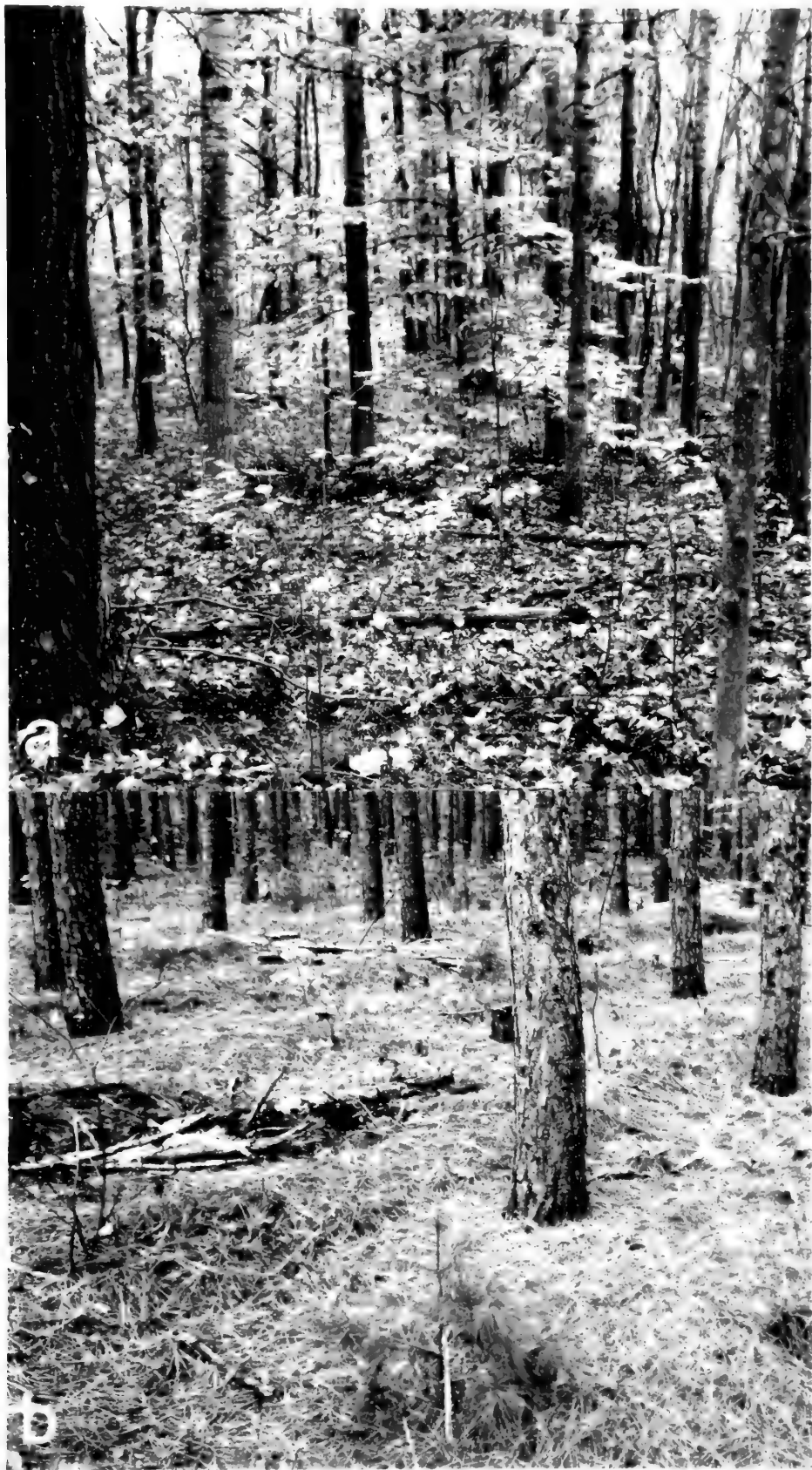


FIGURE 1. Constance Bay study area. a. Northern Red Oak (*Quercus rubra*) – Large-toothed Aspen (*Populus grandidentata*) woods. b. Approximately 60-year-old Red Pine (*Pinus resinosa*) plantation. Both habitats were scrub savannah approximately 60 years ago. Photos: P. M. Catling.

Methods

Data Collection

Species of terrestrial snails and their numbers (both dead and alive) were recorded in ten 1-m² quadrats at 5-m intervals in 20 transects of which ten were in Red Pine plantation and ten were in Northern Red Oak – Large-toothed Aspen woodland. Each quadrat was searched for 30 minutes. No minor adjustments were made to include woody debris or other potentially important microhabitat, but it was occasionally necessary to avoid trees. Usually, little was found after the first 20 minutes of searching; thus, 30 minutes was considered a sufficient amount of search time. Only visual hand-searching was carried out. All leaf litter and the upper 2 mm of hard soil was searched. The survey was conducted during mild, 5–15°C, clear weather in September 2014 before leaf fall. Transects were laid out in such a way as to avoid habitat edges and each other by at least 20 m. They were parallel and 50 m in length. The approximate areas of available habitat within which the survey took place were 10.28 ha for the Northern Red Oak – Large-toothed Aspen woodland and 10.54 ha for the Red Pine plantation.

Identification

Specimens were collected for identification and vouchers identified by the authors were donated to the Canadian Museum of Nature with the assistance of curator Dr. Jean-Marc Gagnon. Living snails were placed in 70% alcohol and, subsequently, dried for storage. Both living snails and empty shells were included in the study and were identified on the basis of shell characteristics using Pilsbry (1939, 1940, 1946, 1948), Burch (1962), and Grimm *et al.* (2010) as well as some recent monographs (e.g., Nekola and Coles 2010) and updates (e.g., Badra 2008; Forsyth and Oldham 2014; Nekola *et al.* 2015). The names of snails used here are taken from Grimm *et al.* (2010) despite some limitations of that work (Nekola 2010a).

Results

Manually searching a defined area, for a prescribed period has been considered an efficient method for estimating diversity and relative abundance of millipedes (Mesibov *et al.* 1995) and should work well for snails provided small species are not overlooked and they are not deep in the soil. Because many micro-snails were recorded and few living snails were found in the upper 2 mm of harder soil, we think that the method was satisfactory for our purposes.

The identification of *Novisuccinea ovalis* (Say, 1817) is appropriate according to the way in which this group of snails is currently defined, although some authors have stressed the taxonomic difficulty of this group (Grimm *et al.* 2010). Other succineids, such as *Catinella vermeta* (Say, 1829), *Oxyloma retusum* (I. Lea, 1834), and *Succinea putris* (L., 1758), occur in this part of Ontario, but these are relatively distinctive genera of

wetlands, shores, and disturbed habitats and differ in size, colour, and/or aperture shape.

The specimens of *Helicodiscus* had relatively broad whorls and a relatively deep umbilicus suggesting *H. parallelus* (Say, 1817) rather than *H. shimaki* Hubricht 1962. *Strobilops* shells clearly had five or six basal and parietal folds and, in a few shells where this could not be reliably evaluated, the spires were convex; thus, all were identified as *Strobilops labyrinthicus* (Say, 1817).

A few taxa identified with “*cf.*” were listed that way because of either inadequate material or complexity of the group. The *Euconulus* are treated as *fulvus* on the basis of relatively weak spiral striae on the base of the shell, but this and other characteristics were found to be difficult to evaluate. Because they are few and only found in the red oak woods, the lack of a positive identification does not affect the comparison. The specimens of *Pupilla muscorum* (L., 1758) had shallow sutures unlike the recently described *P. hudsonianum* Nekola and Coles, 2015 (Nekola *et al.* 2015). The shells of *Columella* were immature.

In the Northern Red Oak – Large-toothed Aspen woodland, 13 species and 661 individuals were recorded, whereas in the Red Pine plantation both the number of species (six) and relative abundance (24 individuals) were much lower (Table 1). There was much variation among the quadrats: 85 contained no snails, whereas 36 snails including six species were found in the quadrat that contained the most snails.

The most abundant species in the Northern Red Oak – Large-toothed Aspen woodland was the succineid snail *N. ovalis* (Figure 2, family Succineidae), which was present in 74 of the 100 quadrats and was represented by 460 individuals. We estimated that there were 46 000 of these snails per ha. The most common species in the Red Pine plantation was *Zonitoides arboreus* (Say, 1816), which was present in 16 quadrats and represented by 17 individuals. This species was the second most common in the Northern Red Oak – Large-toothed Aspen woodland where 70 individuals were found in 34 quadrats. In both habitats *Z. arboreus* was in or on rotting wood. Other species occurring in more than 15% of quadrats in the Northern Red Oak – Large-toothed Aspen woodland were *Strobilops labyrinthicus*, *Glyphyalinia indentata* (Say, 1823), and *Euchemotrema fraternum* (Say, 1824) (Table 1).

Discussion

What was a single scrub savannah habitat approximately 60 years ago diverged into two habitats: a planted conifer plantation and dry deciduous woodland. Ten examples of the conifer plantation differed from ten examples of the deciduous woodland in having less diversity and smaller numbers of terrestrial snails. The data suggest that the diversity and numbers of snails will decline when a savannah or dry deciduous woodland transforms into a conifer plantation. However, the snail fauna can likely be re-established by restoration of the

TABLE 1. Occurrence and numbers of land snails found in 100 1-m² quadrats in a Northern Red Oak (*Quercus rubra*) – Large-toothed Aspen (*Populus grandidentata*) woods and a Red Pine (*Pinus resinosa*) plantation at Constance Bay, Ontario.

Species	Northern Red Oak Large-toothed Aspen woods		Red Pine plantation	
	No. quadrats	No. individuals	No. quadrats	No. individuals
Oval Ambersnail, <i>Novisuccinea ovalis</i> (Say, 1817)	74	460	2	2
Quick Gloss, <i>Zonitoides arboreus</i> (Say, 1816)	34	70	16	17
Maze Pinecone, <i>Strobilops labyrinthicus</i> (Say, 1817)	18	33	1	1
Carved Glyph, <i>Glyphyalinia indentata</i> (Say, 1823)	17	22	0	0
Upland Pillsnail, <i>Euchemotrema fraternum</i> (Say, 1824)	15	22	0	0
Whitelip, <i>Neohelix albolabris</i> (Say, 1817)	7	8	0	0
Immature Polygyridae	7	7	1	1
Compound Coil, <i>Helicodiscus parallelus</i> (Say, 1817)	6	6	0	0
Trumpet Vallonia, <i>Vallonia parvula</i> Sterki, 1893	4	4	0	0
Angular Disc, <i>Discus catskillensis</i> (Pilsbry, 1896)	3	23	0	0
Brown Hive, <i>Euconulus fulvus</i> (Müller, 1774)	2	2	2	2
Widespread Column, <i>Pupilla cf. muscorum</i> (L., 1758)*	2	2	0	0
Bottleneck Snaggletooth, <i>Gastrocopta contracta</i> (Say, 1822)	1	1	0	0
Comb Snaggletooth, <i>Gastrocopta pentodon</i> (Say, 1822)	1	1	0	0
Grovesnail, <i>Cepaea nemoralis</i> (L., 1758)*	0	0	1	1
Toothless Column, <i>Columella cf. edentula</i> (Draparnaud, 1805)	0	0	1	1
Total		661		25

*Introduced.

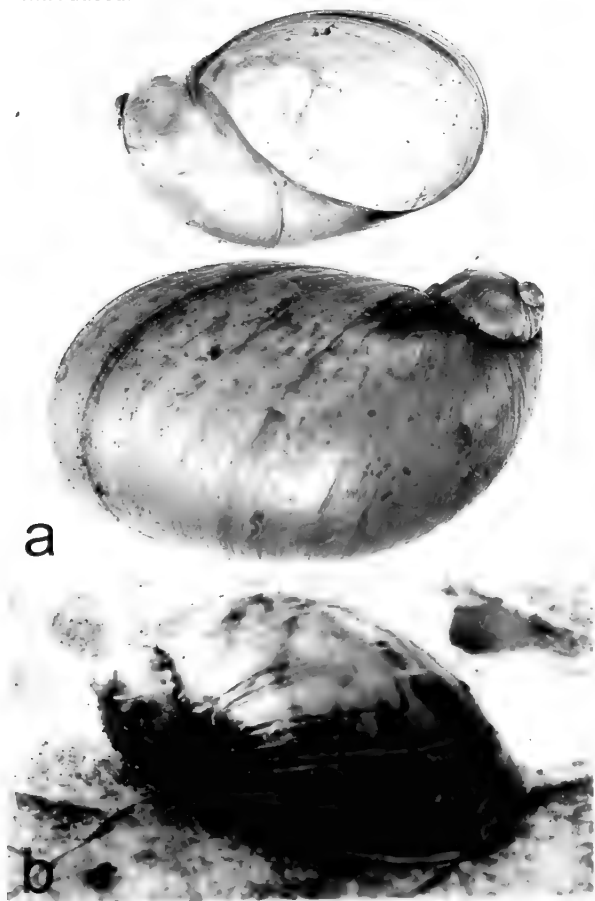


FIGURE 2. Oval Ambersnail (*Novisuccinea ovalis* (Say, 1917)). 10–15 mm in length, were common in the dry Northern Red Oak (*Quercus rubra*) – Large-toothed Aspen (*Populus grandidentata*) woods at Constance Bay with an estimated 46 000 ha. a. Shell with characteristic large aperture and few whorls. b. The animal below the transparent final whorl is blotched. Photos: P. M. Catling and B. Kostiuk.

habitat, as in the case of other flora and fauna (Catling and Kostiuk 2010), leading to a diverse assemblage possibly dominated by the Oval Ambersnail, *N. ovalis* (Figure 2).

The small number of species and relative abundance of terrestrial snails in the conifer plantation was expected on the basis of numerous reports for both conifer forests and conifer plantations (Burch 1955; Karlin 1961; Solem 1984; Bonham *et al.* 2002; Jordan and Black 2012). A characteristic thick layer of pine needle litter occurred in the conifer plantation, but there was much less leaf litter in the dry deciduous woodland and areas of litter accumulation were localized. Downed wood was present in both habitats and substrate moisture appeared to be higher in the conifer plantation. The understory was generally much more extensive in the dry deciduous woodland. Any of these, and other differences, may account for differences in snail populations. The depressed terrestrial snail fauna associated with conifers is often accounted for by the high acidity of the needle duff and lack of decaying broadleaf vegetation (Nekola 2010b).

The habitat of *N. ovalis* is often dry, and this species can survive months of desiccation (Oughton 1948: 75); this snail may occur in large numbers after rain in dry woods (Latchford 1885: 229 *sub Succinea obliqua*). It is generally reported to be most common in upland woods and rock outcrops (Nekola 2003), but Pilsbry (1948: 804) reported it from both moist and dry ground, possibly based on more than one species. Although the Constance Bay habitat of periodically very dry, rolling, and elevated Northern Red Oak – Large-toothed Aspen woodland on well-drained sandy soil may seem to be an unlikely one for snails, *N. ovalis* was not uncommon there. The calculation of 46 000 *N. ovalis* per hectare in the dry deciduous woods draws attention to the potentially significant role of this medium-sized (adult length

at this site 10–15 mm) snail dispersed throughout the ecosystem (74% of quadrats) over an area of 10.28 ha.

Literature Cited

- Badra, P. J.** 2008. Special animal abstract for *Euconulus alderi* (a land snail). Michigan Natural Features Inventory, Lansing, Michigan, USA.
- Bonham, K. J., R. Mesibov, and R. Bashford.** 2002. Diversity and abundance of some ground-dwelling invertebrates in plantation vs. native forests in Tasmania, Australia. *Forest Ecology and Management* 158: 237–247. [https://doi.org/10.1016/S0378-1127\(00\)00717-9](https://doi.org/10.1016/S0378-1127(00)00717-9)
- Burch, J. B.** 1955. Some ecological factors of the soil affecting the distribution and abundance of land snails in eastern Virginia. *Nautilus* 69: 62–69.
- Burch, J. B.** 1962. How to Know the Eastern Land Snails. W. C. Brown, Dubuque, Iowa, USA. <https://babel.hathitrust.org/cgi/pt?id=mdp.39076006431519;view=1up;seq=77>.
- Catling, P. M.** 2013. The cult of the Red Pine — a useful reference for the over-afforestation period of Ontario. *Canadian Field-Naturalist* 127: 198–199. <https://doi.org/10.22621/cfn.v127i2.1462>
- Catling, P. M., and D. F. Brunton.** 2010. Some notes on the biodiversity of the Constance Bay Sandhills. *Trail & Landscape* 44: 123–130.
- Catling, P. M., and B. Kostiuk.** 2010. Successful re-establishment of a native savannah flora and fauna on the site of a former pine plantation at Constance Bay, Ottawa, Ontario. *Canadian Field-Naturalist* 124: 169. <https://doi.org/10.22621/cfn.v124i2.1056>
- Catling, P. M., and B. Kostiuk.** 2015. Grasshopper outing contributes to Constance Bay Biothon. *Trail & Landscape* 49: 103–113.
- Catling, P. M., K. W. Spicer, and D. F. Brunton.** 2010. The history of the Constance Bay Sandhills — decline of a biodiversity gem in the Ottawa valley. *Trail & Landscape* 44: 106–122.
- Forsyth, R. G., and M. J. Oldham.** 2014. Distribution of *Strobilops aeneus* Pilsbry, 1926, in Canada, with two new Ontario records (Mollusca: Gastropoda: Strobilopsidae). *Check List* 10: 397–401. <https://doi.org/10.15560/10.2.397>
- Grimm, F. W., R. G. Forsyth, F. W. Schueler, and A. Karstad.** 2010. Identifying Land Snails and Slugs in Canada: Introduced Species and Native Genera. Canadian Food Inspection Agency, Ottawa, Ontario, Canada.
- Jordan, S. F., and S. H. Black.** 2012. Effects of forest land management on terrestrial mollusks: a literature review. Xerces Society for Invertebrate Conservation, Portland, Oregon, USA.
- Karlin, E. J.** 1961. Ecological relationships between vegetation and the distribution of land snails in Montana, Colorado and New Mexico. *American Midland Naturalist* 65: 60–66. <https://doi.org/10.2307/2423002>
- Latchford, F. R.** 1885. Observations on the terrestrial Mollusca of Ottawa and vicinity. *Transactions of the Ottawa Field-Naturalists' Club* 2: 211–231.
- Mesibov, R., R. J. Taylor, and R. N. Brereton.** 1995. Relative efficiency of pitfall trapping and hand-collecting from plots for sampling of millipedes. *Biodiversity and Conservation* 4: 429–439. <https://doi.org/10.1007/BF00058426>
- Nekola, J. C.** 2003. Terrestrial gastropod fauna of northeastern Wisconsin and the southern Upper Peninsula of Michigan. *American Malacological Bulletin* 18: 21–44. <https://doi.org/10.4003/006.028.0221>
- Nekola, J. C.** 2010a. [Book Review] “Identifying Land Snails and Slugs in Canada” by F. Wayne Grimm *et al.* 2010. *Canadian Field-Naturalist* 124: 67–68. <https://doi.org/10.22621/cfn.v124i1.1042>
- Nekola, J. C.** 2010b. Acidophilic terrestrial gastropod communities of North America. *Journal of Molluscan Studies* 76: 144–156. <https://doi.org/10.1093/mollus/eyp053>
- Nekola, J. C., and B. F. Coles.** 2010. Pupillid land snails of eastern North America. *American Malacological Bulletin* 28: 29–57. <https://doi.org/10.4003/006.028.0221>
- Nekola, J. C., B. F. Coles, and M. Horsák.** 2015. Species assignment in *Pupilla* (Gastropoda: Pulmonata: Pupillidae): integration of DNA-sequence data and conchology. *Journal of Molluscan Studies* 81: 196–216. <https://doi.org/10.1093/mollus/eyu083>
- Oughton, J.** 1948. A zoogeographical study of the land snails of Ontario. Biological series 57. University of Toronto Press, Toronto, Ontario, Canada.
- Pilsbry, H. A.** 1939. Land Mollusca of North America (North of Mexico). Volume 1, Part 1. Monograph 3. Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania, USA.
- Pilsbry, H. A.** 1940. Land Mollusca of North America (North of Mexico). Volume 1, Part 2. Monograph 3. Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania, USA.
- Pilsbry, H. A.** 1946. Land Mollusca of North America (North of Mexico). Volume 2, Part 1. Monograph 3. Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania, USA.
- Pilsbry, H. A.** 1948. Land Mollusca of North America (North of Mexico). Volume 2, Part 2. Monograph 3. Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania, USA.
- Solem, A.** 1984. A world model of land snail diversity and abundance. Pages 6–22 in *World-wide Snails*. Edited by A. Solem and A. C. van Bruggen. Brill/Backhuys, Leiden, Netherlands.
- Spitale, S. P.** 2011. Succession in the understory of Red Pine plantations in southern Ontario. M.Sc. thesis, University of Waterloo, Waterloo, Ontario, Canada.

Received 15 November 2015

Accepted 7 June 2017

Habitat Use by Nuttall's Cottontails (*Sylvilagus nuttallii nuttallii*) at their Northern Range Edge (British Columbia, Canada)

EMILY J. HERDMAN^{1,2,3} and KAREN E. HODGES¹

¹Department of Biology, 1177 Research Road, University of British Columbia Okanagan, Kelowna, British Columbia V1V 1V7 Canada

²Current address: Resource Management, Department of Environment and Parks, Government of Alberta, 250 Diamond Avenue, Spruce Grove, Alberta T7X 4C7 Canada

³Corresponding author: emily.herdman@a.gov.ab.ca

Herdman, Emily J., and Karen E. Hodges. 2017. Habitat use by Nuttall's Cottontails (*Sylvilagus nuttallii nuttallii*) at their northern range edge (British Columbia, Canada). *Canadian Field-Naturalist* 131(2): 133–140. <https://doi.org/10.22621/cfn.v131i2.1827>

In Canada, Nuttall's Cottontails (*Sylvilagus nuttallii nuttallii*) occur in southcentral British Columbia (BC), where they are federally listed as a species of Special Concern due to their presumed small populations and limited distribution in fragmented habitats. Their habitat use and movement patterns are poorly known at this northern edge of their distribution. We used live-trapping, radio-collaring, and fecal pellet surveys to examine Nuttall's Cottontails' use of remaining patches of native habitat as well as use of human-impacted areas. Cottontails were present in low densities and only about half of presumably suitable patches of native sagebrush-steppe were occupied. Cottontails were more likely to occur in shrubby habitat, but at a fine scale cottontails used areas that had a lower density of shrubs and finer substrates. Movement patterns differed significantly between areas of varying habitat quality, with longer movements in natural habitat. One radio-collared male cottontail used anthropogenic habitats adjacent to native habitat; this use corresponds with landowner reports. However, it is not clear whether Nuttall's Cottontails are able to use anthropogenically-impacted areas to maintain populations or in areas where such habitats are not near native habitats. Our results suggest that these animals are rare and occur primarily in remnant patches of shrub-steppe within BC.

Key Words: Nuttall's Cottontail; movement; pellet survey; fragmentation; peripheral population; sagebrush-steppe

Introduction

Nuttall's Cottontail, *Sylvilagus nuttallii nuttallii* (Bachman), is a species of shrub-steppe habitats of the North American Great Basin ecosystems that extend from southern British Columbia, Canada south to Utah, Nevada, and California, USA. In southern British Columbia (BC), Nuttall's Cottontails arrived and spread into the Okanagan and Similkameen valleys in the 1930s and 1940s, at the same time as White-tailed Jackrabbits (*Lepus townsendii*) were being extirpated from this region (Cowan and Hatter 1940; Sullivan *et al.* 1989; Carter *et al.* 1993; Nagorsen 2005). The Nuttall's Cottontail has expanded its BC range to include known areas of appropriate habitat since their first sighting in 1939, moving as far north as Keremeos and Okanagan Mountain Provincial Park (Carter *et al.* 1993; Nagorsen 2005). These cottontails are at the periphery of their northern range; the species is more common in the United States, with the range reaching as far south as Arizona and New Mexico (Chapman 1975). Nuttall's Cottontails can be locally abundant in parts of the USA range (McKay and Verts 1978a,b; Verts *et al.* 1984) and they are legally harvested in Washington and Idaho, adjacent to their Canadian range (WDFW 2015; IFG 2016).

Lagomorphs are significant prey in several ecosystems, including shrub-steppe habitats. In southern BC, Nuttall's Cottontails are likely prey for Coyotes (*Canis latrans*), Great Horned Owls (*Bubo virginianus*), Red-tailed Hawks (*Buteo jamaicensis*), Golden Eagles (*Aquila chrysaetos*), Badgers (*Taxidea taxus*), and Bob-

cats (*Lynx rufus*; COSEWIC 2006). Nuttall's Cottontails are not known to cause significant damage to agricultural crops in the Okanagan and Similkameen valleys where they are found in BC (Sullivan *et al.* 1989), but their use of crops may vary with the availability of natural food.

The BC population of Nuttall's Cottontails is listed as Special Concern under Canada's *Species at Risk Act* (SARA Registry 2017). Despite limited knowledge of their ecology and demography, this listing is based on presumed low numbers in a limited range, and the continued conversion of sagebrush-steppe habitat for agricultural and urban development (COSEWIC 2006). This rabbit species is under-studied, particularly in comparison to other closely-related leporid species. Nuttall's Cottontails are most commonly found in shrub-steppe habitats with Antelope-brush (*Purshia tridentata* (Pursh) DC.) and Big Sagebrush (*Artemisia tridentata* Nutt.; McKay and Verts 1978a; COSEWIC 2006). In BC, shrub cover is a strong predictor of cottontail occupancy (Sullivan *et al.* 1989). Nuttall's Cottontails prefer habitats with refuges in the form of rocky outcrops, where they can escape from predators (Powers and Verts 1971; Johnson and Hansen 1979). In the south Okanagan Valley, Nuttall's Cottontails are predicted to occur in shrubland and grassland habitats below 700 m elevation (Carter *et al.* 1993; COSEWIC 2006). Habitat use by Nuttall's Cottontails shows significant variation across their range. At the extreme southern extent of their range, in New Mexico, Nuttall's Cottontails move into higher elevations and use conifer-

ous forests; their habitat use is expanded enough that they may overlap with Snowshoe Hares (*Lepus americanus*; Frey and Malaney 2006; Malaney and Frey 2006).

The majority of research into Nuttall’s Cottontail has occurred in the USA, raising questions about the extent to which cottontails in their northern range periphery use habitats in the same ways as more southern populations, or are subject to unique habitats and climatic conditions. Here, we address a knowledge gap about northern populations by surveying areas containing suspected high-quality habitats, as well as areas of atypical habitat but with previous sightings or other records. Our goals were to assess relative abundance and to characterize habitat features at two scales that predicted presence or absence of Nuttall’s Cottontails.

Methods

Surveys for cottontails

Our pellet surveys took place in the south Okanagan and Similkameen valleys, BC (49.400°N, 119.669°W),

from May to November in 2007 and 2008. The valleys occur in an area of ecosystem abutment; they contain forested habitats common to more northerly areas and those from the Great Basin ecosystems to the south. We surveyed areas predicted to be suitable Nuttall’s Cottontail habitat based on past sightings and a literature review, resulting in three main habitat types being surveyed: grasslands (*n* = 19), habitats dominated by Antelope-brush (*n* = 8), and sagebrush shrubland (*n* = 12). We further restricted our sites to those below 700 m, as this is the elevation where forest begins to dominate and Snowshoe Hares become more common (Carter *et al.* 1993). Based on these restrictions, Geographic Information System (GIS) maps with habitat overlays were used to choose 33 sites distributed across the area suspected to contain Nuttall’s Cottontails in the south Okanagan and Similkameen regions (Figure 1). In addition, six of the seven live-trapping sites described below were surveyed for pellets; we did not conduct pellet plots at the Naramata live-trapping site as plots had already been completed at a nearby location

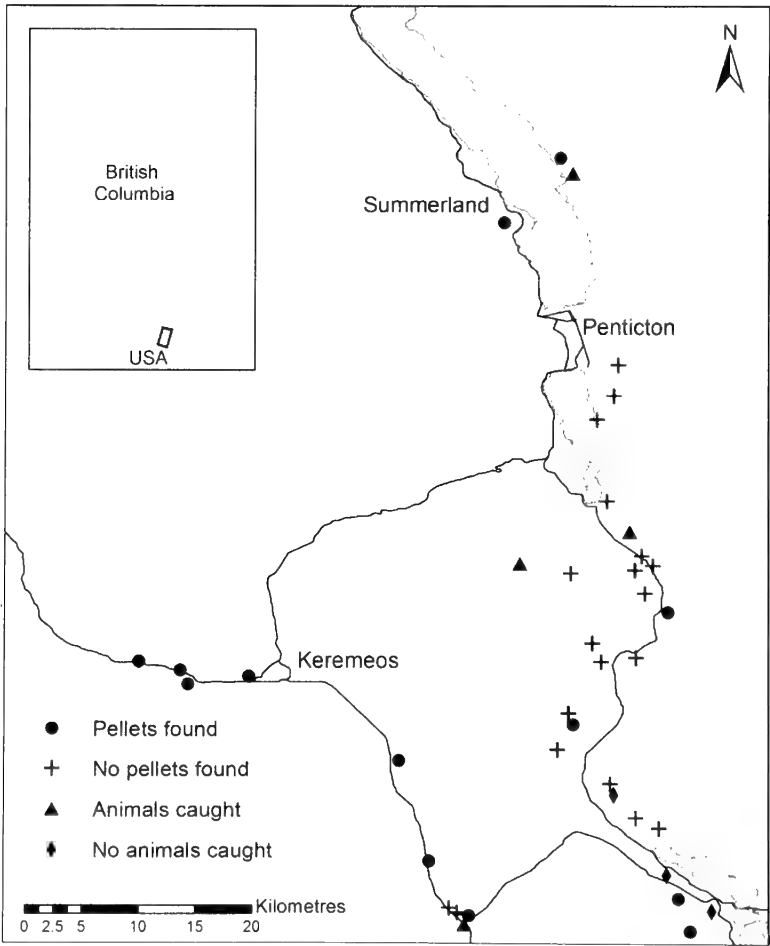


FIGURE 1. Map of south-central British Columbia (Okanagan Valley) showing sampled locations with and without documented presence of Nuttall’s Cottontails (*Sylvilagus nuttallii nuttallii*) in 2007–2008. Dots indicate locations of Nuttall’s Cottontail fecal pellets. Crosses were surveyed for pellets but none were found. Diamonds indicate sites that were trapped but where no animals were caught. Triangles indicate sites where Nuttall’s Cottontails were captured. Six of seven trapped sites also had pellet surveys with pellets found; the seventh trapped site had pellets on a nearby site.

with natural habitat. At each location, we surveyed within a 31.5 ha rectangle (150 × 210 m). Many patches of natural vegetation in the study area are small and irregularly shaped as a result of agricultural and urban development, and these rectangles fit within these patches better than squares would have. The dominant agricultural crops in the region are tree fruits (cherries, apples, peaches, etc.) and wine grapes.

We used fecal pellet counts as a method to survey presence and relative abundance of Nuttall's Cottontails (following Krebs *et al.* 1987, 2001 for Snowshoe Hares). We surveyed 50 transects within each site, with starting points randomly selected in GIS prior to the fieldwork. In the field, we navigated with a handheld Global Positioning System receiver (eTrex, Garmin International Inc., Olathe, Kansas, USA) to the assigned point. At each point, the pellet plot was delineated using a nail placed at the point anchoring a string stretched due true north for 305 cm. Intact pellets were counted if at least half of the pellet was found within 2.55 cm on either side of the string. This produced a pellet plot of the dimensions recommended for lagomorphs (Krebs *et al.* 1987; BC Environment 1998). Pellets were counted only if they were intact and medium to dark brown. We are confident pellet counts represented recent (about one year) or current occupation of a site by cottontails; we had no sites that had only degraded or whitened pellets, so this decision rule did not lead to excluding evidence of cottontail presence. Because our sites were all in non-forested habitats, i.e., habitats that Snowshoe Hares would not use, all pellets were assumed to belong to Nuttall's Cottontails.

At each site, we surveyed vegetation at a pre-determined and randomized subset of 25 of the 50 pellet count locations. We characterized shrub cover to species; shrubs were defined as woody vegetation with multiple stems 50–200 cm tall. We estimated the percentage ground cover in the following categories: grasses, forbs, cactus, biological soil crust (including lichens

and mosses), shrubs, dead wood, litter (dead leaves, needles, forbs), rocks (greater than 25 cm in diameter), cobble (5 cm to 25 cm in diameter), pebbles (2 mm to 5 cm in diameter), and fine substrate (less than 2 mm in diameter). These variables were comprehensive in characterizing ground cover in our study areas.

Live-trapping and radio-telemetry

During 2007–2008, we live-trapped for rabbits at seven pellet locations within the Okanagan Valley (Table 1, Figure 1). These sites were predicted to support Nuttall's Cottontail populations on the basis of habitat and elevation. At all but one location, > 48 traps were deployed in a grid with 30 m spacing between traps. The grid dimensions varied among locations because of the irregular shapes of habitat patches. At the Osoyoos Golf Course, we deployed 30 traps along a line because of limits in the amount and distribution of natural habitat adjacent to the course. We used collapsible live traps (Model 205, Tomahawk Live Trap, Hazelhurst, Wisconsin, USA) baited with alfalfa and apples or carrots and covered traps with wood or tarpaper to protect animals from sun or precipitation. Traps were set in the evening and checked within an hour of sunrise. Trapped animals were aged (juveniles versus adults, based on size), sexed (scrotal testes or engorged nipples or via evertng the genitals to assess morphology), ear-tagged (Self-piercing Ear Tag 1005-4, National Band & Tag Company, Newport, Kentucky, USA), and weighed. Trapping was conducted at every site for at least six nights.

We radio-collared adult cottontails at the Osoyoos Desert Centre (three males, one female) and Osoyoos Golf Course (one male, two females). We used 16 g collars (less than 2.8% body mass; SOM-2380, Wildlife Materials Inc., Murphysboro, Illinois, USA). Each radio-collared animal was followed hourly from 1900–0700 h for a mean of eight nights (range 2–13). We attempted to avoid driving animal movement by remaining greater than 5 m away, using red lights, remaining

TABLE 1. Summary of live-trapping for Nuttall's Cottontails (*Sylvilagus nuttallii nuttallii*) in the south Okanagan Valley, BC. The numbers of traps per site varied because of differences in habitat areas and configurations.

Location	Trapping dates	Total trap nights	# traps	# individuals	# captures	Average pellets/plot	Habitat type
Osoyoos Desert Centre	May, July, Aug., Oct, Nov 2007 and Jan, Apr, Jul 2008	2760	72	34	124	22.31	Antelope-brush shrubland
Osoyoos Golf Course	Aug, Sept, Nov 2007 and Jan, Jul 2008	780	30	19	51	8.34	Antelope-brush shrubland
Bradley's	May–June 2007	597	87	1	1	0.05	Sagebrush shrubland
Blue Mountain	June–July 2007	816	48	0	0	0.20	Antelope-brush shrubland
Naramata	Sept 2007	252	42	0	0	*	Orchard sagebrush shrubland
Nighthawk	May 2007	504	72	0	0	1.34	Sagebrush shrubland
White Lake	June–July 2007	1104	48	0	0	0.00	Sagebrush shrubland

*This site was not sampled for pellets because an adjacent area of sagebrush shrubland was sampled.

quiet, and moving slowly. We could interpret from the radio-signal if animals moved in response to our approach and this was quite rare. We recorded the dominant habitat type (sagebrush shrubland, Antelope-brush shrubland, grassland, orchard, and junkyard) where cottontails were located. In addition, at a fine scale, we recorded the dominant vertical cover type and amount within a 5 m radius of the animal's location. We surveyed the vegetation after the animal had moved away from the fix location.

Statistical analyses

We used analysis of variance (ANOVA) to compare vegetation attributes across the different habitat types for the 39 pellet plot sites. We used logistic regression to relate fine-scale habitat characteristics and presence or absence of cottontail pellets. All calculations were performed using JMP 8 (SAS Institute Inc., Cary, North Carolina, USA). We calculated the average straight-line distance moved per hour for each radio-collared animal and compared these rates using a *t*-test between animals at the Osoyoos Golf Course and the Osoyoos Desert Centre.

Results

Nuttall's Cottontail pellets were found on 49% of sites surveyed (Figure 2). Over all sites, a mean (± 1 SE) of 1.24 ± 0.61 pellets was found per plot. For sites that had pellets, we found 2.54 ± 1.19 pellets per plot. Antelope-brush and sagebrush-dominated habitats were more likely to have cottontail pellets than were grasslands, although pellets were found on all habitat types (Figure 2).

At a fine scale, the three habitat types surveyed for pellets varied substantially in vegetation/ground cover characteristics. Unsurprisingly, percent shrub cover was lowest in grassland habitat ($6.0 \pm 1.4\%$), with Antelope-brush ($17.9 \pm 3.0\%$) and sagebrush ($16.9 \pm 2.3\%$) shrubland showing near equal amounts (ANOVA, $F_{2,36} = 5.77$, $P = 0.001$). Cobble and pebble ground cover was lower in Antelope-brush shrubland and litter was lower in sagebrush shrubland (Table 2). Rock outcrops are common throughout the Okanagan Valley and were present on all sites surveyed for pellets. The presence of pellets of Nuttall's Cottontails was best predicted by percent shrub cover and the percent of ground cover that was biological crust, shrub or fine substrate (Table 3). Cottontail pellets were positively associated with fine substrate, but negatively associated with shrub cover and biological crust.

We captured Nuttall's Cottontails on only three of seven trapped sites in 2007–2008, despite an effort of 6813 trap nights (Table 1). One site yielded only one capture. We had a capture rate of 5% for two other sites (Osoyoos Golf Course and Osoyoos Desert Centre), with 175 captures of 55 individuals (39 adults, 16 juveniles; 30 females, 23 males, 2 unknown) caught over 3540 trap nights. The three locations where cottontails were trapped had pellet densities of 10.23 ± 6.50 pellets/plot (mean ± 1 SE). The sites where no animals were captured had pellet densities of 0.51 ± 0.42 pellets/plot.

Radio-collared cottontails were tracked for an average of 70 locations per animal. Cottontails tracked at the Osoyoos Desert Centre moved an average straight-

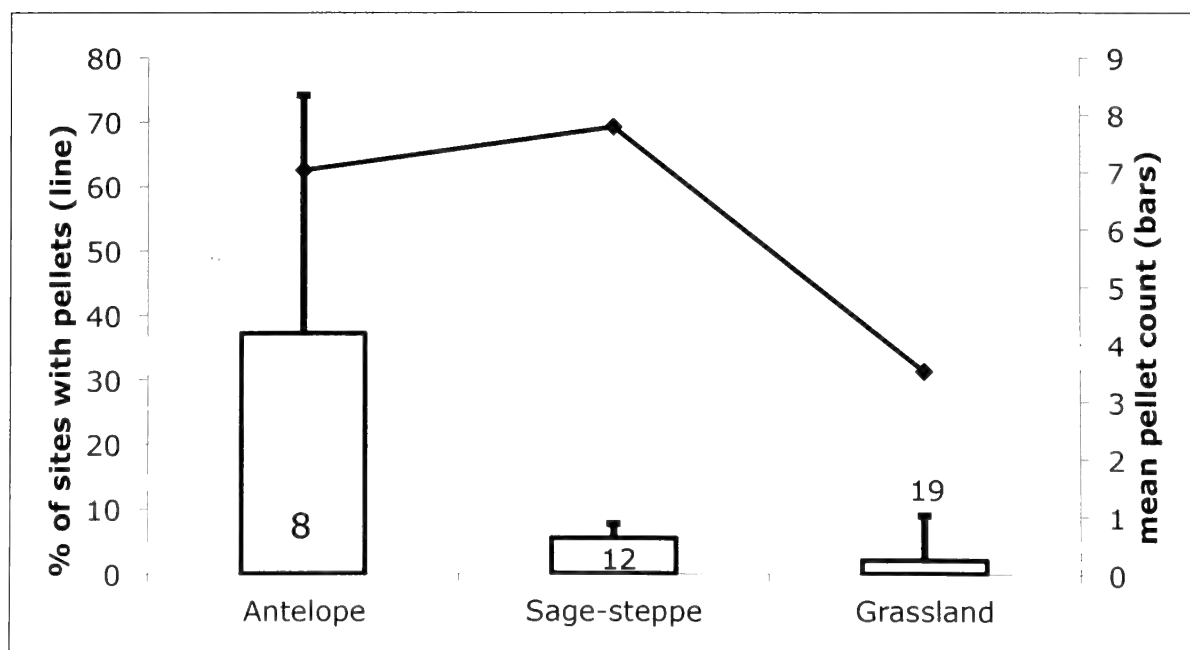


FIGURE 2. Mean Nuttall's Cottontail (*Sylvilagus nuttallii nuttallii*) pellet counts (bars) by habitat type (Antelope = Antelope-brush shrubland, Sage-steppe = sagebrush shrubland). Sample sizes are indicated for each habitat type and mean pellets \pm SE are shown. Percent of sites with pellets is reported for each habitat type (line).

TABLE 2. Ground cover characteristics for each habitat type surveyed for Nuttall's Cottontails (*Sylvilagus nuttalli nuttalli*). Values are reported as means across sites \pm 1 SE. ANOVAs were used to compare habitat characteristics across habitat types.

Percent ground cover	Antelope-brush shrubland (n = 8)	Sagebrush shrubland (n = 12)	Grassland (n = 19)	F _{2,36}	P
Grass	23.2 \pm 4.0	27.4 \pm 5.1	27.4 \pm 2.9	1.46	0.238
Cactus	3.2 \pm 1.3	4.5 \pm 2.7	0.9 \pm 0.3	0.79	0.538
Biological crust	28.6 \pm 5.6	25.0 \pm 4.8	16.9 \pm 2.6	2.24	0.086
Forbs	8.8 \pm 1.9	10.0 \pm 5.1	7.5 \pm 1.6	0.17	0.952
Shrub	4.3 \pm 1.6	3.9 \pm 1.1	2.6 \pm 0.6	0.58	0.680
Dead wood	5.2 \pm 2.3	2.8 \pm 0.6	4.7 \pm 1.0	0.82	0.523
Rocks	1.0 \pm 0.8	2.3 \pm 0.6	6.2 \pm 2.0	1.93	0.129
Cobble	1.1 \pm 0.7	5.0 \pm 1.9	6.8 \pm 2.5	2.66	0.050
Pebble	0.9 \pm 0.7	3.2 \pm 0.8	5.1 \pm 1.7	5.05	0.003
Fine substrate	12.7 \pm 3.3	8.9 \pm 4.0	10.5 \pm 3.0	0.41	0.802
Litter	10.5 \pm 4.8	3.3 \pm 1.5	9.0 \pm 3.0	3.40	0.020

TABLE 3. Logistic regressions quantifying the relationship between presence/not detected of Nuttall's Cottontail (*Sylvilagus nuttalli nuttalli*) pellets with measured habitat characteristics including both vertical shrub cover and 12 components of percent ground cover (including shrubs covering ground). Individual logistic regressions were completed for each habitat characteristic, followed by a stepwise multiple logistic regression to determine which habitat characteristics were involved in the best-fit model. The best-fit model included % shrub cover ($P = 0.0006$), % grass ($P < 0.0001$), % cactus ($P = 0.0346$), % deadwood ($P = 0.0010$) and % fine substrate ($P = 0.0001$). The best-fit model correctly classified 66.4% of sites into pellets presence versus pellets not detected categories.

Vegetation characteristics	β_0	Estimate	χ^2	P	% classified correctly
% vertical shrub cover	1.455	-0.114	7.208	0.018	78.1
% ground cover:					
Grass	-1.221	0.051	3.928	0.064	—
Cactus	0.293	-0.082	1.538	0.281	—
Biological crust	1.337	-0.056	5.205	0.033	70.0
Forbs	0.273	-0.020	0.408	0.541	—
Shrub ground cover	0.970	-0.267	5.574	0.038	68.1
Dead wood	-0.400	0.126	2.302	0.162	—
Rocks	0.380	-0.074	1.779	0.214	—
Cobble	0.579	-0.107	4.158	0.103	—
Pebble	0.035	0.020	0.105	0.748	—
Fine substrate	-0.752	0.096	7.595	0.030	75.0
Litter	-0.322	0.063	3.591	0.093	—

line distance of 51.0 ± 2.8 m/h while those at the Osoyoos Golf Course moved 34.2 ± 3.0 m/h ($t = -4.1$, $P < 0.01$). Cottontails at the Osoyoos Golf Course had access to anthropogenic habitat in the form of a junkyard, the golf course greens, and an orchard; most of the radio-collared animals restricted activity in anthropogenic habitat to the golf course greens. However, one male cottontail at the Osoyoos Golf Course often used both the junkyard and the orchard, with 66% of his locations within these non-native habitats. The natural habitat at both locations was dominated by Antelope-brush shrubland with patches of sagebrush shrubland and grassland. Cottontails at the Osoyoos Golf Course were located 74% of the time in Antelope-brush shrubland, 7% in sagebrush shrubland, and 19% in anthropogenic habitat. At the Osoyoos Desert Centre, radio-collared animals were located 53% of the time in Antelope-brush shrubland, 5% in sagebrush shrubland, 40% in grassland habitat, and 2% in anthropogenic habitat. Within a 5 m radius around each ani-

mal location, the amount of cover varied with habitat type. In grasslands this was $17.6 \pm 0.8\%$, $9.5 \pm 4.3\%$ in anthropogenic landscapes, $74.8 \pm 3.9\%$ in sagebrush shrubland, and in Antelope-brush shrubland it was $67.8 \pm 1.4\%$.

Discussion

Our results suggest that Nuttall's Cottontails occur at extremely low densities in scattered localities within our study area. Although we sampled sites of apparently suitable habitat, about half had no sign of cottontails. For sites that did have cottontails, the trapping rates and the very low pellet counts both indicate low densities. Similarly, opportunistic and low intensity surveys in 2009 found low numbers of cottontail pellets in only 10 of 18 sites in the south Okanagan (Marks and Young 2009). Given the fragmented nature of remaining shrub-steppe habitats in this region, we suspect Nuttall's Cottontail may occur in a metapopulation and that some patches are simply too small or too

isolated to support cottontails. Detailed demographic work would be necessary to confirm whether cottontail populations occur in discrete areas linked by dispersal, whether dispersal is high enough to reflect a connected but very low density regional population, or whether populations are actually isolated in habitat fragments. We note that the Management Plan for the Nuttall's Cottontail (Environment Canada 2015) specifies that key goals are to identify and protect habitats and connectivity corridors. This suggests that the patchy distribution of cottontails as a major concern for their management.

Nuttall's Cottontail pellets were more likely to be present in shrubby than in grassy habitat. This is consistent with previous research on this species both in BC and in the USA (McKay and Verts 1978a; MacCracken and Hansen 1982; Sullivan *et al.* 1989). Fecal pellets were more common in more open habitats within shrublands, i.e., with locally lower densities of shrubs and with fine substrate. This result agrees with Pierce *et al.* (2011), who found *Sylvilagus* spp. pellet densities in Utah were relatively high in sagebrush-steppe areas near to agricultural lands or in areas of steppe with lower shrub densities. We are not certain if these patterns arise because more open habitats have preferred forage plants, enable better predator detection, or have some other attraction for the animals. Given that cottontails eat grasses, forbs, and shrubs (MacCracken and Hansen 1984; Verts *et al.* 1984), our results showing preferred habitat types and microhabitats containing these resources may reflect foraging decisions. We believe different pellet degradation across sites can be ruled out as affecting our detection rates, because these arid environments are likely to prolong rather than shorten the persistence of fecal pellets and Snowshoe Hare pellets can persist for years in wet forests (Krebs *et al.* 1987).

Natural habitat patches in southcentral BC are found within a matrix of human-impacted habitat and developed areas, potentially impacting movement decisions by Nuttall's Cottontails. Nuttall's Cottontail use of these anthropogenic habitats in this study was dominated by a single radio-collared male who used orchards and a junkyard. However, informal discussions with landowners of orchards and wineries indicated that Nuttall's Cottontails make some use of these non-traditional habitats. Based on these conversations and our own observations, we do not think cottontails are making heavy use of these agricultural areas, although we did not survey these areas. In the context of metapopulations or patch-matrix analyses, we do not yet know if these agricultural landcovers enable cottontails to disperse among the remnant patches of high quality shrub-steppe habitat or whether they act as barriers to movement. We suspect movements by Nuttall's Cottontails between high-quality patches are limited, in part based on the low movement rates we detected and because other *Sylvilagus* species do not show high dispersal rates or distances (Robinson *et al.* 2016).

Within the two sites with radio-collared cottontails, animals had a much higher percentage of horizontal cover nearby when they were within Antelope-brush and sagebrush shrubland than when they were in grassland or anthropogenic cover types. We cannot tell if this pattern only reflects cover availability or also reflects actual selection at a fine scale for such cover, but we suspect both are at play. Crowell *et al.* (2016) found that captive Nuttall's Cottontails in Washington preferred eating near cover. The cottontails also showed significant differences in movement speeds in relation to availability of natural habitat. Nuttall's Cottontails at the Osoyoos Desert Centre, a prime area of natural habitat, had longer hourly movements than did animals near the Osoyoos Golf Course. We suspect these patterns reflect higher resource availability in the natural habitats; at the Osoyoos Golf Course, animals had quite limited natural patches of habitat and appeared to move within them, except for one male who regularly used anthropogenic habitats.

Our results are similar to patterns seen in other *Sylvilagus* species. Animals in this genus seem to prefer native environments, but are sometimes capable of using anthropogenic landscapes if there is a substantial amount of cover in the human-altered areas. For example, Eastern Cottontails (*S. floridanus*) foraging in college campuses and gardens in Illinois preferred areas with substantially higher shrub cover (Baker *et al.* 2015). The authors interpreted this as being at least partly an anti-predator tactic. Hunt *et al.* (2014) found Eastern Cottontails in a city park in Chicago occurred in higher densities and potentially had smaller home ranges than did animals in native habitats. But this context differed from ours in that the park was surrounded by development, rather than adjacent to wild habitats. In Missouri, Eastern Cottontails were positively associated with increasing urban cover near habitat fragments and negatively associated with Coyotes, suggesting habitat selection by cottontails is affected by predation risk (Jones *et al.* 2016). Robinson *et al.* (2016) examined Swamp Rabbits (*S. aquaticus*) in southern Illinois that use patches of bottomland hardwood and appear to exist in metapopulations with limited dispersal. For them, agricultural lands seem to be more of a barrier than habitat.

Collectively, our results suggest that there is a small, fragmented population of Nuttall's Cottontails in southcentral BC. Although cottontails can use some agricultural and recreational habitats, such sites did not seem to be as resource-rich or to support as many animals as native habitats. Near their southern range limit in New Mexico, Nuttall's Cottontails use higher elevation sites (> 3000 m) and even some forested areas. This suggests that cottontails are capable of using a wide range of habitats even if some types are clearly strongly preferred. In BC, we have not observed this breadth of habitat use by the cottontails. Instead, cottontails here seem to be quite limited in their distribution. As land conversion

continues in the south Okanagan, we expect some patches of natural habitat will see the extirpation of cottontails as patches become smaller, more isolated, or surrounded by habitat types that are more difficult for cottontails to cross. We encourage more survey efforts, radio-tracking, and genetic analysis to determine if the existing populations are isolated or connected. At present, it seems likely that ongoing habitat loss is severely damaging this species in BC.

Acknowledgements

We thank Stephanie Pascuzzo, Sharon Watson, Astrid Boeckelmann, Natalie Melaschenko, Adam Collins, Natasha Lukey, Jordan Edwards, and other volunteers who assisted with field work. We also thank Orville Dyer (British Columbia Ministry of the Environment) for help gaining land access and determining plot locations, the Canadian Wildlife Service, Parks Canada, The Osoyoos Golf and Country Club, The Osoyoos Desert Centre, BC Parks, the Nature Trust of British Columbia, The Dominion Radio Astrophysical Observatory (National Research Council of Canada), and private landowners for allowing access to their properties. Funding for this project was provided by Environment Canada and the University of British Columbia Okanagan. Trapping and radio-collaring were conducted under protocol A06-0322 of the Animal Care Committee of the University of British Columbia.

Literature Cited

- Baker, M. A. A., S. E. Emerson, and J. S. Brown.** 2015. Foraging and habitat use of eastern cottontails (*Sylvilagus floridanus*) in an urban landscape. *Urban Ecosystems* 18: 977–987. <https://doi.org/10.1007/s11252-015-0463-7>
- BC Environment.** 1998. Inventory for hares and cottontails: standards for components of British Columbia's biodiversity No. 23. Ministry of Environment, Lands and Parks, British Columbia, Victoria, Canada.
- Carter, D., A. Harestad, and F. L. Bunnell.** 1993. Status of Nuttall's cottontail in British Columbia. Environment Wildlife Working Report No. WR-56. B.C. Ministry of Environment, Lands and Parks, Victoria, British Columbia, Canada.
- Chapman, J. A.** 1975. *Sylvilagus nuttallii*. *Mammalian Species* (American Society of Mammalogists) 56: 1–3. <https://doi.org/10.2307/3503902>
- COSEWIC.** 2006. COSEWIC assessment and update status report on the Nuttall's Cottontail *nuttallii* subspecies *Sylvilagus nuttallii nuttallii* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, Ontario, Canada.
- Cowan, I. M., and I. Hatter.** 1940. Two mammals new to the known fauna of British Columbia. *Murrelet* 21: 9.
- Crowell, M. M., L. A. Shipley, M. J. Camp, J. L. Rachlow, J. S. Forbey, and T. R. Johnson.** 2016. Selection of food patches by sympatric herbivores in response to concealment and distance from a refuge. *Ecology and Evolution* 6: 2865–2876. <https://doi.org/10.1002/ece3.1940>
- Environment Canada.** 2015. Management Plan for the Nuttall's Cottontail *nuttallii* subspecies (*Sylvilagus nuttallii nuttallii*) in Canada. Species at Risk Act Management Plan Series. Environment Canada, Ottawa, Ontario, Canada.
- Frey, J. K., and J. L. Malaney.** 2006. Snowshoe hare (*Lepus americanus*) and mountain cottontail (*Sylvilagus nuttallii*) biogeography at their southern range limit. *Journal of Mammalogy* 87: 1175–1182. <https://doi.org/10.1644/05-MAMM-A-374R2.1>
- Hunt, V. M., S. B. Magle, C. Vargas, A. W. Brown, E. V. Lonsdorf, A. B. Sacerdote, E. J. Sorley, and R. M. Santymire.** 2014. Survival, abundance, and capture rate of eastern cottontail rabbits in an urban park. *Urban Ecosystems* 17: 547–560. <https://doi.org/10.1007/s11252-013-0334-z>
- IFG (Idaho Fish and Game).** 2016. Upland Game, Furbearer, and Turkey 2016-17 Seasons and Rules. Accessed 1 July 2017. <https://idfg.idaho.gov/sites/default/files/seasons-rules-upland-hunting-rules-2016-2017.pdf>
- Johnson, M. K., and R. M. Hansen.** 1979. Foods of cottontails and woodrats in south-central Idaho. *Journal of Mammalogy* 60: 213–215. <https://doi.org/10.2307/1379778>
- Jones, B. M., M. V. Cove, M. A. Lashley, and V. L. Jackson.** 2016. Do coyotes *Canis latrans* influence occupancy of prey in suburban forest fragments? *Current Zoology* 62: 1–6. <https://doi.org/10.1093/cz/zov004>
- Krebs, C. J., B. S. Gilbert, S. Boutin, and R. Boonstra.** 1987. Estimation of snowshoe hare population density from turd transects. *Canadian Journal of Zoology* 65: 565–567. <https://doi.org/10.1139/z87-087>
- Krebs, C. J., R. Boonstra, V. Nams, M. O'Donoghue, K. E. Hodges, and S. Boutin.** 2001. Estimating snowshoe hare population density from pellet plots: a further evaluation. *Canadian Journal of Zoology* 79: 1–4. <https://doi.org/10.1139/z00-177>
- MacCracken, J. G., and R. M. Hansen.** 1982. Herbaceous vegetation of habitat used by blacktail jackrabbits and Nuttall cottontails in southeastern Idaho. *American Midland Naturalist* 107: 180–184. <https://doi.org/10.2307/2425199>
- MacCracken, J. G., and R. M. Hansen.** 1984. Seasonal foods of blacktail jackrabbits and Nuttall cottontails in southeastern Idaho. *Journal of Range Management* 37: 256–259. <https://doi.org/10.2307/3899150>
- Malaney, J. L., and J. K. Frey.** 2006. Summer habitat use by snowshoe hare and mountain cottontail at their southern zone of sympatry. *Journal of Wildlife Management* 70: 877–883. <https://doi.org/10.2193/0022-541X>
- Marks, D., and V. Young.** 2009. Nuttall's Cottontail (*Sylvilagus nuttallii*) pellet surveys in the southern Okanagan Valley, British Columbia, 2009. B.C. Ministry of the Environment. Penticton, British Columbia, Canada.
- McKay, D. O., and B. J. Verts.** 1978a. Habitat preference and dispersion of Nuttall's cottontails. *Northwest Science* 52: 363–368.
- McKay, D. O., and B. J. Verts.** 1978b. Estimates of some attributes of a population of Nuttall's cottontails. *Journal of Wildlife Management* 42: 159–168. <https://doi.org/10.2307/3800704>
- Nagorsen, D. W.** 2005. Nuttall's cottontail, *Sylvilagus nuttallii*. Pages 106–109 in *The Rodents and Lagomorphs of British Columbia*. Royal British Columbia Museum Handbook, Victoria, British Columbia, Canada.
- Pierce, J. E., R. T. Larsen, J. T. Flinders, and J. C. Whiting.** 2011. Fragmentation of sagebrush communities: does an increase in habitat edge impact pygmy rabbits? *Animal Conservation* 14: 314–321. <https://doi.org/10.1111/j.1469-1795.2010.00430.x>
- Powers, R. A., and B. J. Verts.** 1971. Reproduction in the Mountain Cottontail rabbit in Oregon. *Journal of Wildlife Management* 35: 605–613. <https://doi.org/10.2307/3799763>

- Robinson, C. D., J. C. Crawford, L. Corcoran, E. M. Schaubert, and C. K. Nielsen.** 2016. Metapopulation viability of swamp rabbits in southern Illinois: potential impacts of habitat change. *Journal of Mammalogy* 97: 68–79. <https://doi.org/10.1093/jmammal/gyv154>
- SARA (Species at Risk) Registry.** 2017. Species Profile, Nuttall's Cottontail. Accessed 30 May 2017. http://sara.registry.gc.ca/species/speciesDetails_e.cfm?sid=163#ot18.
- Sullivan, T. P., B. Jones, and D. S. Sullivan.** 1989. Population ecology and conservation of the mountain cottontail, *Sylvilagus nuttallii nuttallii*, in southern British Columbia. *Canadian Field-Naturalist* 103: 335–340.
- Verts, B. J., S. D. Gehman, and K. J. Hundertmark.** 1984. *Sylvilagus nuttallii*: A semi-arboreal lagomorph. *Journal of Mammalogy* 65: 131–135. <https://doi.org/10.2307/1381211>
- WDFW (Washington Department of Fish and Wildlife).** 2015. Summary of general hunting season dates: small game. Accessed 19 October 2015. http://wdfw.wa.gov/hunting/regulations/summary_hunting_dates.html#small_game.

Received 13 July 2016

Accepted 30 May 2017

Note

A Review and the Conservation Implications of Aquatic Behaviour and Drowning in Jumping Mice (Dipodidae: Zapodinae)

JENNIFER K. FREY

Department of Fish, Wildlife and Conservation Ecology, New Mexico State University, Las Cruces, New Mexico 88003 USA;
email: jfrey@nmsu.edu

Frey, Jennifer K. 2017. A review and the conservation implications of aquatic behaviour and drowning in jumping mice (Dipodidae: Zapodinae). *Canadian Field-Naturalist* 131(2): 141–143. <https://doi.org/10.22621/cfn.v131i2.1869>

Jumping mice (Dipodidae: Zapodinae) have a generalized terrestrial quadrupedal locomotion with specializations for saltatory and scansorial locomotion. I reviewed first-hand accounts of aquatic behaviour in the literature and confirmed that jumping mice are semi-aquatic, using both primitive quadrupedal paddling on the surface as well as the more derived simultaneous bipedal pelvic paddling while swimming underwater. Although proficient swimmers, jumping mice are also prone to drowning, especially in human-made pools. Management of populations of jumping mice with conservation concern should consider potential hazards faced by jumping mice in an aquatic environment.

Key Words: Endangered species; jumping mouse; *Eozapus*; *Zapus*; *Napaeozapus*; pitfall trap

Introduction

The jumping mice (Dipodidae: Zapodinae) include four North American species, Meadow Jumping Mouse (*Zapus hudsonius*), Pacific Jumping Mouse (*Zapus trinotatus*), Western Jumping Mouse (*Zapus princeps*), and Woodland Jumping Mouse (*Napaeozapus insignis*), all found in Canada (Banfield 1974), and one palearctic species, Chinese Jumping Mouse (*Eozapus setchuanus*; Wilson and Reeder 2005). The Zapodinae are generalized quadrupeds, but they are the sister taxon to the more speciose jerboas (Dipodinae, Allactaginae, Cardiocraniinae, and Euchoreutinae), which are highly specialized for arid environments and use highly derived bipedal locomotion (Lebedev *et al.* 2012).

All species of jumping mice are commonly associated with wet habitats and are frequently found along streams and rivers or in marshes, swamps, and other freshwater wetlands (Kruttsch 1954). Consequently, an ability to swim might be a valuable adaptive trait for life in these environments. However, jumping mice are considered to have a generalized terrestrial quadrupedal mode of locomotion with some morphological specialization for saltatory and scansorial locomotion (Samuels and Van Valkenburgh 2008; Wright and Frey 2014). Other than somewhat small external pinnae with an antitragal flap, which can cover the external auditory meatus, and reduced size of testes and scrotum, jumping mice lack many of the specialized adaptations often found in semi-aquatic small mammals, such as interdigital webbing or fringes, dense non-wettable underfur, laterally compressed tail, valvular nares, and nictitating membranes (Kruttsch 1954).

Because of their association with fragile and declining wetland habitats, some populations of jumping mice are of conservation concern, and two forms (*Zapus hudsonius preblei* and *Z. h. luteus*) are now listed under the United States *Endangered Species Act* (Malaney and Cook 2013; USFWS 2014). Although no jumping

mice have been assessed by the Committee on the Status of Endangered Wildlife in Canada (SARA Public Registry 2017), it is important to understand more clearly the behavioural relation of jumping mice with water, which is a frequent component of their habitat. For instance, some endangered populations of jumping mice occur in irrigated valleys where human-constructed canals and ditches convey water and could pose barriers to jumping mice if they are poor swimmers (e.g., Wright and Frey 2015). Thus, the purpose of this report was to review existing, first-hand information about aquatic behaviour in jumping mice (swimming or drowning) and to evaluate the conservation implications of that information.

Methods

I searched for published, first-hand observations of aquatic behaviour in jumping mice. Search terms included: *Zapus*, *Napaeozapus*, *Eozapus*, aquatic, swim, swam, swimming, drown, drowned, and drowning. Search engines included: Google Scholar, Google Books, and Web of Science. I categorized accounts of swimming by species and by nature of the observation (i.e., free-ranging animals or animals forced to swim in laboratory or natural water body). I categorized accounts of drowning by species and the type of water body (i.e., natural or artificial). Quotes and references to first-hand observations of swimming and drowning are detailed in supplementary material Appendices S1 and S2, respectively.

Results and Discussion

Swimming

I found 18 papers that described swimming behaviour in Zapodinae (Appendix S1). Of the observations where the species was identified, 13 were of *Z. hudsonius*, three were of *Z. princeps*, and three were *N. insignis*; no information about aquatic behaviour was

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalists' Club.

found for *Eozapus*. Most of the reports were anecdotal observations of free-ranging animals. Four accounts were of animals forced to swim: Quimby (1951) observed five *Z. hudsonius* that were taken out into a lake and observed from a boat; Whitaker (1963) forced two *Z. hudsonius* to swim, although it was not stated where the observation occurred; Dagg and Windsor (1972) recorded data from a *Z. hudsonius* forced to swim in an aquarium; and Wrigley (1972) observed a *N. insignis* forced to swim in an aquarium.

Although swimming behaviour in jumping mice has not been rigorously tested, these first-hand accounts of swimming behaviour allow some conclusions to be made. Jumping mice enter water both accidentally (e.g., following an erratic jump when frightened) and intentionally. Jumping mice are capable of swimming on top of water, underwater, and against a current. Most observers thought that the jumping mice swam with ease and relatively swiftly. Duration of swimming was up to about 5 minutes. Jumping mice swam underwater for up to about 1 minute before surfacing for air. Underwater swimming usually occurred about 10–30 cm below the surface, but up to about 45 cm below the surface.

In parallel with their dual quadrupedal and saltatory modes of terrestrial locomotion, jumping mice exhibit two major modes of swimming. In all cases propulsion is via the limbs, and the elongated hindlimbs, feet, and toes, which are normally adaptations associated with saltatory locomotion (Banfield 1974), serve double duty as powerful swimming devices. On the surface, jumping mice may swim via quadrupedal paddling, which involves alternate use of both limbs in a vertical plane, as typified by a Dog (*Canis familiaris*; Fish 1996). This is considered the most primitive form of drag-based swimming propulsion, and it is used by both terrestrial and semi-aquatic mammals (Fish 1996). However, jumping mice were more frequently observed using simultaneous pelvic paddling, especially when swimming underwater. In this mode, which is used by more derived semi-aquatic mammals, such as the River Otter (*Lontra canadensis*), propulsion is via simultaneous strokes of the hind limbs (Fish 1996). Surface swimming is energy inefficient because of the increased drag at the surface (i.e., wave drag). Because wave drag increases with speed, the relatively slow quadrupedal paddling economizes energy expenditures when swimming on the surface. However, underwater bipedal paddling offers greater energy efficiency and speed. The optimum depth for reducing wave drag is greater than three body diameters, which is consistent with observations of jumping mice swimming about 10–30 cm underwater (Fish 1996).

Although bipedal paddling is relatively efficient because it reduces interference from the other limbs, *N. insignis* was also observed to use simultaneous pelvic paddling in conjunction with simultaneous pectoral paddling when swimming on the surface (Wrigley 1972). In this mode, the forelimbs stroked as the hind limbs were brought up to the body, which was followed

by the propulsive stroke of the hind limbs. Thus, the limb motions resembled the saltatory hop on land. The overall effect of a swimming jumping mouse using this mode was a dorsal rocking motion that created an audible rhythmic splashing in time with the strokes. Presumably the actions of the forelimbs helped keep the head above water during this more vigorous surface swimming mode.

Jumping mice can transition from surface swimming to underwater swimming by diving. Although most mammals can swim, underwater swimming is uncommon and is generally limited to species that live in close association with water (Dagg and Windsor 1972). When jumping mice are swimming underwater, air is apparently trapped by the fur, which makes the animals appear silvery. However, Wrigley (1972) reported that the pelage of *N. insignis* did not hold air as well as that of deer mice (*Peromyscus*) and, thus, provided less buoyancy. Dagg and Windsor (1972) reported that *Z. hudsonius* swam horizontally on the surface of the water with its back submerged (in contrast with animals with dense fur, which allows them to float with their backs above water) and that, as the fur became wetted and they lost buoyancy, their body position shifted to a 25° angle to the water surface.

The tail is not used in swimming, either for propulsion or as a rudder, as it either drags behind limply or is carried arched up in the middle. In other semi-aquatic mammals, the tail is often laterally compressed; however, the tail of jumping mice is narrow and roundish in cross section providing relatively little surface area. Swimming jumping mice are able to steer purposefully to travel to specific points; the exact mechanism for steering is unknown but presumably is similar to that of other semi-aquatic rodents (Fish *et al.* 2002).

Drowning

I found 11 accounts of jumping mice drowning: ten free-ranging *Z. hudsonius* and one captive neonatal *N. insignis* (Appendix S2). All instances of drowning in free-ranging *Z. hudsonius* where the nature of the water body could be determined ($n = 8$) were in small artificial pools of liquid that acted as pitfall traps: milk pan, water tub, post hole, fish hatchery pond, pitfall traps filled with water, goldfish pond, plastic sheeting filled with rain water, plastic wading pool. It seems likely that jumping mice inadvertently enter these pools, perhaps as a result of their jumping behaviour or via scansorial locomotion in overhanging vegetation. However, they were unable to escape because of steep or slick walls and relatively deep fluid that prevents effective jumping.

Conservation implications

Jumping mice are semi-aquatic and capable of both surface and more advanced underwater swimming. Thus, small bodies of water likely do not represent barriers to them, and small streams may provide important escape habitat. However, jumping mice appear to tire of swimming after several minutes, which would limit their ability to cross larger bodies of water.

Although capable swimmers, jumping mice also seem to be particularly vulnerable to drowning in both natural and human-constructed pools of liquid, such as post holes, goldfish ponds, and fish hatchery runs. Compared with other small mammals, jumping mice may be more vulnerable to drowning in pools because of their normal modes of locomotion and escape behaviours; they may inadvertently enter pools, including artificial above-ground pools, through their saltatory locomotion or via their scansorial climbing in overhanging vegetation (Wright and Frey 2014). Further, the normal escape behaviour of a frightened jumping mouse consists of a few erratic ricochetal hops followed by an abrupt stop and remaining motionless (Whitaker 1963). However, a ricochetal hop may not be possible if the mouse is in water that is too deep or it may be ineffective if the pool sides are too close or steep to allow escape. It is also possible that steep or slippery sides preclude jumping mice from climbing out of pools. Jumping mice appear to be particularly vulnerable to capture in pitfall traps (Williams and Braun 1983; Handley and Kalko 1993; Kalko and Handley 1993; Murphy *et al.* 2007). Augmentation of water-filled pitfall traps with slabs of wood still resulted in large numbers of dead rodents, including *Zapus* (Murphy *et al.* 2007), although it is unknown to what extent addition of other structures in pitfall traps (e.g., sticks, strings) could facilitate escape by jumping mice while also retaining target species, such as amphibians.

Thus, because pitfall traps or plastisc reptile cover sheets can partly fill with water or rain, they should not be used in areas with vulnerable populations of jumping mice. Smooth, steep-sided canals and ditches also might pose a drowning hazard. Some techniques used for fish sampling or angling, such as electrofishing or submerged minnow traps, may be a concern in areas occupied by vulnerable populations of jumping mice. Management of vulnerable populations should consider potential impacts of large aquatic predators such as American Bullfrog (*Lithobates catesbeianus*), Brown Trout (*Salmo trutta*), and black bass (*Micropterus* spp.), which could target swimming jumping mice as prey.

Literature Cited

- Banfield, A. W. F.** 1974. The Mammals of Canada. University of Toronto Press, Toronto, Ontario, Canada.
- Dagg, A. I., and D. E. Windsor.** 1972. Swimming in northern terrestrial mammals. *Canadian Journal of Zoology* 50: 117–130. <https://doi.org/10.1139/z72-019>
- Fish, F. E.** 1996. Transitions from drag-based on lift-based propulsion in mammalian swimming. *American Zoologist* 36: 628–641. <https://doi.org/10.1093/icb/36.6.628>
- Fish, F. E., J. Smelstoy, R. V. Baudinette, and P. S. Reynolds.** 2002. Fur does not fly, it floats: buoyancy of pelage in semi-aquatic mammals. *Aquatic Mammals* 28: 102–112.
- Handley, C. O., Jr., and E. K. V. Kalko.** 1993. A short history of pitfall trapping in America, with a review of methods

currently used for small mammals. *Virginia Journal of Science* 44: 19–26.

- Kalko, E. K. V., and C. O. Handley, Jr.** 1993. Comparative studies of small mammal populations with transects of snap traps and pitfall arrays in southwest Virginia. *Virginia Journal of Science* 44: 3–18.
- Krutzsch, P. H.** 1954. North American jumping mice (genus *Zapus*). University of Kansas Publications. Museum of Natural History 7: 349–472. Accessed 31 August 2017. <http://www.gutenberg.org/files/40110/40110-h/40110-h.htm>.
- Lebedev, V. S., A. A. Bannikova, M. Pages, J. Pisano, J. R. Michaux, and G. I. Shenbrot.** 2012. Molecular phylogeny and systematics of Dipodoidea: a test of morphology-based hypotheses. *Zoologica Scripta* 42: 231–249. <https://doi.org/10.1111/zsc.12002>
- Malaney, J. L., and J. A. Cook.** 2013. Using biogeographic history to inform conservation: the case of Preble's meadow jumping mouse. *Molecular Ecology* 22: 6000–6017. <https://doi.org/10.1111/mec.12476>
- Murphy, R. K., R. A. Sweitzer, and J. D. Albertson.** 2007. Occurrences of small mammal species in a mixed-grass prairie in northwestern North Dakota. *Prairie Naturalist* 39: 91–95.
- Quimby, D. C.** 1951. The life history and ecology of the jumping mouse, *Zapus hudsonius*. *Ecological Monographs* 21: 61–95. <https://doi.org/10.2307/1948646>
- Samuels, J. X., and B. Van Valkenburgh.** 2008. Skeletal indicators of locomotor adaptations in living and extinct rodents. *Journal of Morphology* 269: 1387–1411. <https://doi.org/10.1002/jmor.10662>
- SARA (Species at Risk Act) Public Registry.** 2017. Species at risk public registry. Government of Canada, Ottawa, Ontario, Canada. Accessed 20 June 2017. <http://sararegistry.gc.ca/default.asp?lang=En&n=24F7211B-1>.
- USFWS (United States Fish and Wildlife Service).** 2014. Determination of endangered status for the New Mexico meadow jumping mouse throughout its range. Final rule. *Federal Register* 79: 33119–33137.
- Whitaker, J. O., Jr.** 1963. A study of the meadow jumping mouse, *Zapus hudsonius* (Zimmerman), in central New York. *Ecological Monographs* 33: 215–254. <https://doi.org/10.2307/1942627>
- Williams, D. F., and S. E. Braun.** 1983. Comparison of pitfall and conventional traps for sampling small mammals. *Journal of Wildlife Management* 47: 841–845.
- Wilson, D. E., and D. M. Reeder.** 2005. Mammal Species of the World: A Taxonomic and Geographic Reference. Third edition. Johns Hopkins University Press, Baltimore, Maryland, USA.
- Wright, G. D., and J. K. Frey.** 2014. Herbeal feeding behavior of the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*). *Western North American Naturalist* 74: 231–235. <https://doi.org/10.3398/064.074.0210>
- Wright, G. D., and J. K. Frey.** 2015. Habitat selection by the endangered New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) on an irrigated floodplain. *Journal of Fish and Wildlife Management* 6: 112–129. <https://doi.org/10.3996/062014-JFWM-044>
- Wrigley, R. E.** 1972. Systematics and Biology of the Woodland Jumping Mouse, *Napaeozapus insignis*. University of Illinois Press, Chicago, Illinois, USA.

Received 25 October 2016

Accepted 20 June 2017

SUPPLEMENTARY MATERIAL:

APPENDIX S1: First-hand accounts of swimming behaviour in the Zapodinae.

APPENDIX S2: First-hand accounts of drowning in the Zapodinae.

Searching for Black Swift (*Cypseloides niger*) Nests in Southern British Columbia

PAUL G. LEVESQUE^{1,3} and CHRISTINE A. ROCK²

¹2258 Oxford Street, Vancouver, British Columbia V5L 1G1 Canada

²Environmental Resources Management Inc., 1111 West Hastings, Vancouver, British Columbia V6E 2J3 Canada

³Corresponding author: paulglevesque@gmail.com

Levesque, Paul G., and Christine A. Rock. 2017. Searching for Black Swift (*Cypseloides niger*) nests in southern British Columbia. *Canadian Field-Naturalist* 131(2): 144–150. <https://doi.org/10.22621/cfn.v131i2.1805>

Black Swifts (*Cypseloides niger*) are thought to breed throughout southern British Columbia, however few nests have been described in the region. Population trend estimates from British Columbia show significant declines, prompting the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) to assess Black Swift as Endangered in Canada. We identified potential nesting locations and searched for nests at 16 sites in southern British Columbia between 2001 and 2015. Two active Black Swift nests were discovered during surveys: Brandywine Falls south of Whistler, and Highfalls Creek Falls northwest of Squamish. The Brandywine Falls nest was revisited annually from 2009 to 2015, and the nest was active during at least five of the seven years of monitoring. Evening surveys were not effective for detecting Black Swift nest attendance.

Key Words: Black Swift; *Cypseloides niger*; aerial insectivore; nesting; British Columbia; Brandywine Falls; Highfalls Creek

Introduction

The Alaskan and Canadian breeding range of Black Swift (*Cypseloides niger* (Gmelin, 1789)) includes southeastern Alaska, mountainous areas of southwestern Alberta, and the southern half of British Columbia (American Ornithologists' Union 1998). However, nesting has not been confirmed in Alaska (Johnson *et al.* 2008), and few Black Swift nest sites have been documented in Alberta (Bent 1940; Kondla 1973; Holroyd and Holroyd 1987) and British Columbia (Jobin 1955; Beebe 1959; Grant 1966; Campbell *et al.* 1990; Tyson 2004; Levesque 2015). Using Breeding Bird Survey (BBS) data, Partners in Flight has estimated that British Columbia has 86% (60 000) of the North American breeding population of Black Swifts (Partners in Flight Science Committee 2013). The main challenges in locating Black Swift nests are the cryptic and inaccessible nest locations often situated near waterfalls and deep canyons (Lowther and Collins 2002) and long foraging sessions resulting in infrequent nest attendance (Marin 1999).

The Black Swift is an aerial insectivore; a group of birds that is experiencing population declines in Canada (Nebel *et al.* 2010). Based on BBS data, the long-term (1973 to 2012) population trend estimates that Black Swifts in Canada have declined at an annual rate of 6.5% (Environment Canada 2014). The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has assessed the Black Swift as Endangered (COSEWIC 2015). Long-term monitoring of Black Swift nests in California has documented a breeding range contraction at coastal sites (Roberson and Collins

2008). The causes of the decline in the Black Swift population are poorly understood.

Increasing the number of known Black Swift nesting locations is a conservation priority for this species. Annual nest site fidelity is very high, with many sites being used for decades (Kondla 1973; Collins and Foerster 1995; Levad *et al.* 2008; Levesque 2015); this strongly suggests that nest sites are important habitat and are in need of protection. Because Black Swifts spend most of their time in flight, nest sites are the only locations to answer basic questions regarding life history traits such as longevity, age of first breeding, and annual and lifetime productivity.

Currently, the best available monitoring program for estimating population trends of Black Swifts is the North America BBS. However, the BBS methodology has detectability issues for monitoring Black Swift populations in North America. This results in low confidence in survey estimates (Wiggins 2004; Levad 2007; Partners in Flight Science Committee 2013; COSEWIC 2015; Sauer *et al.* 2017), in part due to the species' limited breeding distribution and the inaccessibility of its preferred nesting habitat (Wiggins 2004). It has been argued that the Partners in Flight Black Swift population estimates based on BBS data are most likely overestimated (Levad 2007). Annual nest monitoring at multiple sites throughout the species' northern breeding range would provide a better method of determining population trends.

Given the lack of known Black Swift nesting sites in Canada, the importance of nest sites, and concerns about population declines, our objectives were to locate addi-

tional nest sites in southern British Columbia, and to comment on inventory methodology. If British Columbia is home to 86% of the North American breeding population, (up to 60000 Black Swifts; Partners in Flight Science Committee 2013), there must be many undiscovered nest sites.

Methods

We identified potential Black Swift nesting sites in southern British Columbia by using Google to search terms such as “waterfalls” + “British Columbia”. We prioritized search results by ranking images against nest site attributes observed in Colorado by Knorr (1961, 1993). If a site lacked one or more of Knorr’s site attributes (high physical relief, close proximity to flowing water, inaccessible to terrestrial predators, darkness, open flight corridors to the nests, and suitable niches for nests) the site received a lower rank and was deemed a lower priority for a site visit.

Nest searches were conducted at potential nesting sites following methods in Schultz and Levad (2001) within the known breeding season in British Columbia (early June to early September; Campbell *et al.* 1990). Surveyors searched potential nest sites for the presence of active nests or signs of occupancy (i.e., presence of adults) during midday and in favourable weather. Nest searches were conducted during the day by

methodically scanning all of the substrate surrounding waterfalls using 10 × 42 binoculars and a 15–45 × 60 field scope. Once all of the visible substrate had been searched for nests, the observer(s) moved to a new vantage point and continued scanning the substrate. When additional observers were present, they watched the general area around the waterfall and recorded the presence/absence of adult Black Swifts. Once a nest was located, the site was revisited in following years, when possible, to determine site fidelity and re-occupancy.

Evening surveys followed methods in Schultz and Levad (2001) and were conducted to determine whether Black Swifts were using the waterfall for nesting or roosting. Observers positioned themselves at the bottom of the waterfall when possible, and watched for Black Swifts returning to or leaving the waterfall during the last two hours of daylight. The survey was terminated once it was too dark to observe Black Swifts.

Between 2001 and 2015, 16 potential Black Swift nesting sites were surveyed on Vancouver Island (*n* = 7), Vancouver/Sea to Sky area (*n* = 6), and the southern interior (*n* = 3; Figure 1). All sites, including those deemed low suitability, were surveyed at least once in daylight. During daytime surveys, we conducted 30 h of nest searching (scanning substrate) and 42 h of watching for adult Black Swift flying near or into the waterfalls.

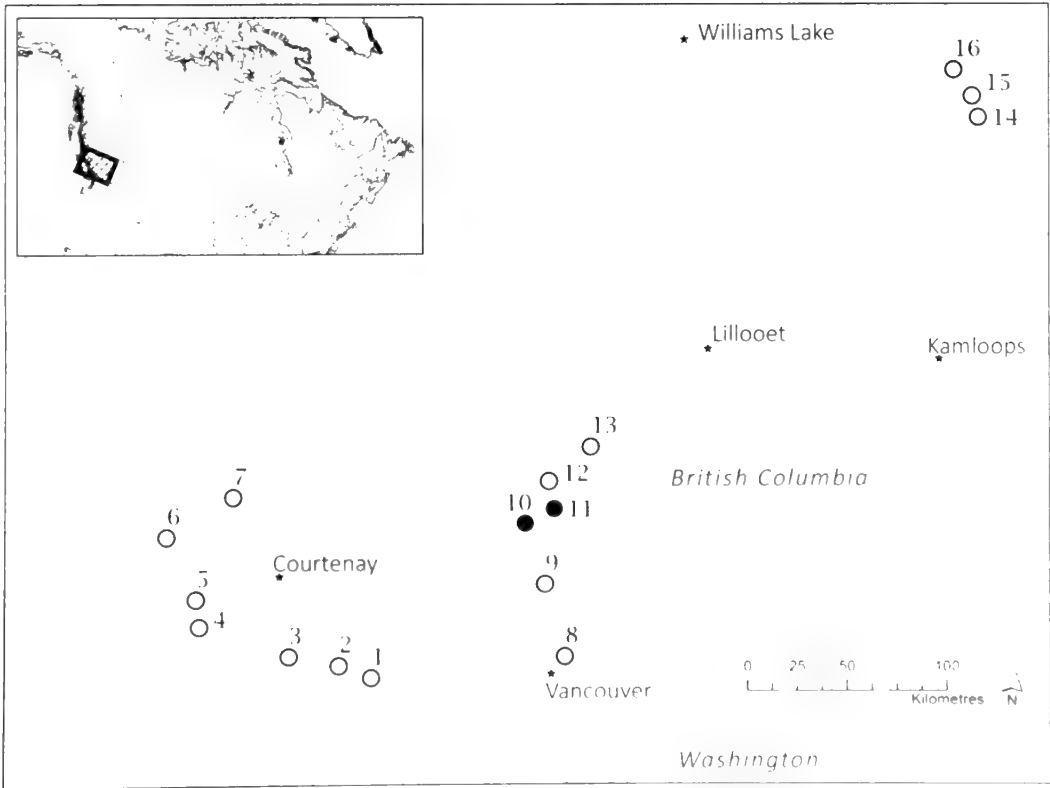


FIGURE 1. Black Swift (*Cypseloides niger*) nesting surveys were conducted at seven sites on Vancouver Island: 1 Englishman River Falls, 2 Little Qualicum Falls, 3 Stamp Falls, 4 Della Falls, 5 Myra Falls, 6 Lady Falls, 7 Elk Falls. Surveys were conducted at six sites in the Vancouver Sea to Sky area: 8 Lynn Canyon, 9 Shannon Falls, 10 Highfalls Creek, 11 Brandywine Falls, 12 Alexander Falls, 13 Nairn Falls. Surveys were conducted at three sites in the southern interior: 14 Spahats Falls, 15 Moul Falls, and 16 Helmcken Falls. Solid circles ● indicate nest locations, open circles ○ indicate survey sites where nests were not found.

Results

Twelve of the 16 sites visited met all of Knorr’s (1961, 1993) physical requirements for Black Swift nesting habitat. Adult Black Swifts were observed flying over three sites on five occasions, and one adult was seen flying into an active nest on three occasions (Table 1). Active Black Swift nests were located at Brandywine Falls and Highfalls Creek Falls (Table 1).

During daytime surveys on 26 July 2004, an adult Black Swift was observed attending a nest behind Brandywine Falls in Brandywine Provincial Park,

approximately 14 km south of Whistler (50.036°N, 123.119°W). Brandywine Falls is a plunge type waterfall that drops 70 m into a large pool. The nest was approximately 25 m below the crest of the waterfall, and was positioned behind the eastern edge of the falls. The nest was positioned on a small ledge on a larger section of undercut rock that was approximately 2 m from the main flow of the waterfall. The nest was made entirely of moss, and the nest and rock surface immediately surrounding the nest was wet (Figure 2).

TABLE 1. Summary of sites visited, survey dates, effort, and Black Swifts (*Cypseloides niger*) observed during day, evening, and nest monitoring surveys, 2001 to 2015.

Site name	Date	Nest searching (h)	Watching falls (h)	Black Swifts observed	Number of observers	Total time at site (h)
DAY SURVEYS						
English River Falls	27 Jun 2004	2.0	0.0	0	1	2.0
Little Qualicum	13 Jun 2004	1.0	1.0	0	1	2.0
Stamp Falls	28 Jun 2004	1.0	1.0	0	2	2.0
Della Falls	3 Aug 2001	3.0	6.0	0	2	9.0
Myra Falls	29 Jun 2004	1.0	1.0	0	2	2.0
Myra Falls	7 Aug 2004	1.0	1.0	0	2	2.0
Lady Falls	8 Aug 2004	2.0	2.0	0	2	4.0
Elk Falls	7 Aug 2004	1.5	1.5	0	2	3.0
Lynn Canyon	7 Aug 2010	2.0	2.0	0	2	4.0
Shannon Falls	26 Jul 2004	1.0	0.0	0	1	1.0
High Falls Creek	25 Jul 2015	2.0	2.0	5* 1†	2	4.0
Brandywine Falls	26 Jul 2004	2.0	2.0	1†	1	4.0
Brandywine Falls	2 Aug 2004	0.0	9.0	1† 1†	3	9.0
Brandywine Falls	3 Aug 2004	1.0	1.0	1§	2	2.0
Brandywine Falls	5 Aug 2004	1.5	1.5	5* 1§	2	3.0
Alexander Falls	3 Aug 2004	1.0	1.0	0	2	2.0
Narin Falls	4 Aug 2004	2.0	2.0	0	2	4.0
Spahat Falls	21 Aug 2010	1.0	1.0	0	2	2.0
Moul Falls	22 Aug 2010	1.0	2.0	0	2	3.0
Helmcken Falls	21 Aug 2010	2.0	2.0	0	2	4.0
EVENING SURVEYS						
English River Falls	13 Jun 2004	0.0	2.0	6*	1	2.0
English River Falls	21 Jul 2004	0.0	3.0	0	1	3.0
English River Falls	27 Jun 2004	0.0	2.5	1*	1	2.5
English River Falls	5 Aug 2004	0.0	4.0	2*	2	4.0
Myra Falls	29 Jun 2004	0.0	4.0	0	2	4.0
Myra Falls	7 Aug 2004	0.0	4.0	0	2	4.0
Lynn Canyon	26 Jul 2013	0.0	2.0	0	1	2.0
Brandywine Falls	3 Aug 2004	0.0	4.0	1§	2	4.0
Alexander Falls	2 Aug 2004	0.0	4.5	0	3	4.5
NEST MONITORING						
Brandywine Falls	23 Jul 2009	1.0	1.0	1† 1†	2	2.0
Brandywine Falls	8 Aug 2010	1.0	1.0	0	2	2.0
Brandywine Falls	30 Aug 2011	0.5	0.5	n/a	2	1.0
Brandywine Falls	5 Aug 2012	1.0	1.0	1† 1§	2	2.0
Brandywine Falls	3 Aug 2013	1.0	1.0	1§	2	2.0
Brandywine Falls	2 Aug 2014	1.0	1.0	1§	2	2.0
Brandywine Falls	25 Jul 2015	1.0	1.0	1†	2	2.0

*Adult Black Swift(s) flying above the waterfall.
†Adult Black Swift(s) at nest.
‡Adult Black Swift observed flying into the nest.
§Black Swift nestling observed, no adult at nest.
n/a, unable to view nest due to high water.



FIGURE 2. Two adult Black Swifts (*Cypseloides niger*) attending the nest at Brandywine Falls, 2 August 2004. Photo: L. Savard

The Black Swift nest at Brandywine Falls was revisited each breeding season 2009–2015 (Table 1). The same nest used in 2004 was reused in 2009, 2012, 2013, 2014, and 2015, but was not active on 10 August 2010, and the nest could not be viewed on the 30 June 2011 visit due to high water levels obscuring the nest. Adult Black Swifts were seen flying into the active nest in 2004, 2009, and 2012.

During daytime surveys on 25 July 2015, an adult Black Swift was observed attending a nest on the eastern side of Highfalls Creek Falls, 27.3 km northwest of Squamish (49.944°N, 123.296°W). Highfalls Creek flows over a three-tiered plunge type waterfall approximately 100 m high. The upper two tiers are approximately 10–15 m high, and the lower section is approximately 80 m high. The nest was 3 m from the eastern edge of the lower tier, 15 m from the top of the lowest tier (Figure 3). This nest was made of moss, and the nest and the surrounding area was dry.

Evening surveys were conducted on nine evenings at five sites. Black Swifts were not observed flying into waterfalls during any of the evening surveys (30 observer hours); this includes four observer hours at the active Brandywine Falls nest. Black Swifts were ob-

served flying approximately 100 m above Englishman River Falls on two of the four evening surveys.

Discussion

Identifying potential Black Swift nesting sites by examining images of waterfalls collected from internet searches was effective. However, site visits revealed that some required physical attributes (particularly: physical relief, suitable niches, and direct sunlight) were not reliably determined from photographs. There was a bias toward readily accessible waterfalls being well documented by the public, and remote or more inaccessible sites being undocumented.

Searching for Black Swift nests by methodically scanning substrate during daytime surveys resulted in locating two active nests. Because observers could not safely access vantage points that permitted viewing of all potential nesting substrate, some active nests could have gone undetected. The waterfalls obscured some potential nesting substrate, and this was most problematic during high water flow in June and early July. Site visits in the latter half of July and August when water volumes tend to be lower may increase success in locating active nests. Schultz and Leivad (2001) also recom-



FIGURE 3. Nest location of Black Swift (*Cypseloides niger*) at Highfalls Creek Falls, denoted by the black square in the center of the image. 25 July 2015. Photo: C. Rock.

mend conducting daytime nest searches in late July and August to avoid high water flow, and they noted that adult nest attendance was more frequent in the 12 days after hatching.

Black Swift nest occupancy monitoring data in British Columbia are limited, partly due to the lack of known nest sites and partly to the lack of a formal monitoring program. Our annual monitoring of the Brandywine Falls nest (2009 to 2015) showed high annual site reuse. Although the nest was not active on 8 August 2010, at that late date it is possible that a nest was initiated, but failed. Nest failures have been documented in Colorado; Hirshman *et al.* (2007) monitored 160 Black Swift nesting attempts over an 11 year period, and observed 35 nest failures. There is likely a trade-off between surveying for nests in the latter half of July and August, when water levels have subsided, and detecting failed nesting attempts. Potential sites should therefore be surveyed for more than one breeding season to determine occupancy.

The strength of evening surveys is to detect sites where active nests are undetectable. Nesting can be confirmed by observing adult Black Swifts flying into the site to attend the nest at dusk (Foerster and Collins 1990). Evening surveys have been used to estimate the number of nests at sites and to estimate the size of regional populations (Foerster and Collins 1990; Levad *et al.* 2008). We observed Black Swifts flying well above the forest canopy during evening surveys, but we

did not observe Black Swifts flying into waterfalls. Furthermore, we did not detect Black Swifts during an evening survey at Brandywine Falls while monitoring the active nest. In 2003, the American Bird Conservancy conducted an ambitious Black Swift nesting inventory that involved 103 field observers conducting 513 h of evening surveys at 82 waterfalls from northern California to southeast Alaska, with the majority of surveys conducted in Oregon, Washington, and Alaska (Altman 2003). The project resulted in the location of two nest sites, including one active nest at Cascade Falls near Mission, British Columbia located after an evening detection on 2 August 2003 (Tyson 2004). Black Swifts were observed flying into waterfalls at four additional sites, but nests were not located.

The effectiveness of evening surveys may vary spatially and temporally through the breeding season. Udvary (1954) reported that low-pressure weather systems concentrated foraging flocks of Black Swifts in coastal areas of southern British Columbia and suggested that low-pressure systems would result in long distance, multiday foraging trips. The passage of low-pressure systems is a regular occurrence in June and July in British Columbia and could influence the frequency of evening nest attendance. In southern California, Marin (1999) noted that the timing of nest attendance shifted from mornings (8:00–12:00) to evenings (18:00–20:00) once Black Swift nestlings were 15 days old and that morning feedings were not observed after

the nestlings were 30 days old. Following the known nesting phenology in Hirshman *et al.* (2007), Black Swift nestlings would be 15 and 30 days old on 10 August and 25 August, respectively. If food deliveries are more common in the mornings during incubation and the first half of the nestling phase, conducting evening surveys during this period may result in low detection rates, assuming the timing of nest attendance in British Columbia is similar to the timing in southern California.

We recommend that determining the timing and frequency of Black Swift nest attendance throughout the nesting cycle, and in relation to weather systems, should be a research priority for the British Columbia population. If Black Swift nest attendance can be determined, the timing of nest searches could then be optimized and would increase the number of known nest sites in the region. We recommend that at least 10 to 15 active Black Swift nest sites be monitored across a range of habitat types (i.e., coastal, dry interior, and eastern British Columbia) for at least a decade to understand reproductive trends and their influence on population trends.

Acknowledgements

We thank Laurie Savard for her assistance in the field, and for her photography. Joel Crawford (Environmental Resources Management Inc.) created the map for Figure 1. Greg Sharam (Environmental Resources Management Inc.) provided helpful review comments on an early version of the manuscript. The manuscript was greatly improved by comments from Anthony Gaston and two anonymous reviewers.

Literature Cited

- Altman, B.** 2003. Inventorying Black Swift populations at waterfalls in the Northern Pacific Rainforest Bird Conservation Region. American Bird Conservancy. Accessed 20 February 2016. <http://www.orbirds.org/blswreport.pdf>.
- American Ornithologists' Union.** 1998. Check-list of North American Birds. Seventh edition. American Ornithologists' Union, Washington, D.C., USA.
- Beebe, F.** 1959. A nesting record of a Black Swift. The Murrelet 40: 9–10. <https://doi.org/10.2307/3535279>
- Bent, A. C.** 1940. Life histories of North American Cuckoos, Goatsuckers, Hummingbirds, and their Allies. United States National Museum Bulletin 176. Washington, D.C., USA.
- Campbell, R. W., N. K. Dawe, I. McTaggart-Cowan, J. M. Cooper, G. W. Kaiser, and M. C. E. McNall.** 1990. The Birds of British Columbia. Volume II—Nonpasserines (Birds of Prey Through Woodpeckers). Royal British Columbia Museum and Canadian Wildlife Service, Victoria, British Columbia, Canada.
- Collins, C. T., and K. S. Foerster.** 1995. Nest site fidelity and adult longevity in the Black Swift (*Cypseloides niger*). North American Bird Bander 20: 11–14.
- COSEWIC (Committee on the Status of Endangered Wildlife in Canada).** 2015. COSEWIC assessment and status report on the Black Swift *Cypseloides niger* in Canada. COSEWIC, Gatineau, Quebec, Canada. Accessed 20 February 2016. http://www.registrelep-sararegistry.gc.ca/document/default_e.cfm?documentID=2756.
- Environment Canada.** 2014. North American Breeding Bird Survey-Canadian trends website, Data-version 2012. Environment Canada, Gatineau, Quebec, Canada. Accessed 27 March 2017. <https://wildlife-species.canada.ca/breeding-bird-survey-results>.
- Foerster, K. S., and C. T. Collins.** 1990. Breeding distribution of the Black Swift in southern California. Western Birds 21: 1–9.
- Grant, J.** 1966. A Black Swift nest in British Columbia. Canadian Field-Naturalist 80: 60–61.
- Hirshman, S. E., C. Gunn, and R. G. Levad.** 2007. Breeding phenology and success of Black Swifts in Box Canyon, Ouray, Colorado. Wilson Journal of Ornithology 119: 678–685. <https://doi.org/10.1676/06-112.1>
- Holroyd, G. L., and W. M. Holroyd.** 1987. Black Swift nests at Maligne Canyon, Jasper National Park. Alberta Naturalist 17: 46–48.
- Jobin, L.** 1955. Notes on the Black Swift and Vaux Swift at their nesting sites in central British Columbia. Canadian Field-Naturalist 69: 131–132.
- Johnson, J. A., B. A. Andres, and J. A. Bissonette.** 2008. Birds of the major mainland rivers of southeast Alaska. General Technical Report PNW-GTR-739. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon, USA. Accessed 10 August 2017. https://www.fs.fed.us/pnw/pubs/pnw_gtr739.pdf.
- Knorr, O. A.** 1961. The geographical and ecological distribution of the Black Swift in Colorado. Wilson's Bulletin 73: 155–170.
- Knorr, O. A.** 1993. Black Swift (*Cypseloides niger*) nesting site characteristics: some new insights. Avocetta 17: 139–140.
- Kondla, N. G.** 1973. Nesting of the Black Swift at Johnston's Canyon, Alberta. Canadian Field-Naturalist 87: 64–65.
- Levad, R. G., K. M. Potter, C. W. Shultz, C. Gunn, and J. G. Doerr.** 2008. Distribution, abundance, and nest-site characteristics of Black Swifts in the southern Rocky Mountains of Colorado and New Mexico. Wilson Journal of Ornithology 120: 331–338. <https://doi.org/10.1676/07-049.1>
- Levad, R. G.** 2007. The coolest bird—a natural history of the Black Swift and those who have pursued it. American Birding Association, Colorado Springs, Colorado. Accessed 27 March 2016. <http://www.aba.org/thecoolestbird.pdf>.
- Levesque, P. G.** 2015. Relocating a historical Black Swift nest and the importance of nest sites to the species. Northwestern Naturalist 96: 243–246. <https://doi.org/10.1898/1051-1733-96.3.243>
- Lowther, P. E., and C. T. Collins.** 2002. Black Swift (*Cypseloides niger*). In The Birds of North America. Edited by P. G. Rodewald. Cornell Lab of Ornithology, Ithaca, New York, USA. <https://doi.org/10.2173/bna.676>
- Marín, M.** 1999. Food, foraging, and timing of breeding of the Black Swift in California. Wilson Bulletin 111: 30–37.
- Nebel, S., A. Mills, J. D. McCracken, and P. D. Taylor.** 2010. Declines of aerial insectivores in North America follow a geographic gradient. Avian Conservation and Ecology: Ecologie et conservation des oiseaux 5:1. <https://doi.org/10.5751/ACE-00391-050201>
- Partners in Flight Science Committee.** 2013. Population estimates database, version 2013. Accessed 27 March 2016. <http://rmbo.org/pifpopestimates>.

- Roberson, D., and C. T. Collins.** 2008. Black Swift (*Cypseloides niger*). Pages 245–249 in *California Bird Species of Special Concern: a Ranked Assessment of Species, Subspecies, and Distinct Populations of Birds of Immediate Conservation Concern in California*. Studies of Western Birds Number 1. Edited by W. D. Shuford, and T. Gardali. Western Field Ornithologists, Camarillo, California and California Department of Fish and Game, Sacramento, California, USA.
- Sauer, J. R., D. K. Niven, J. E. Hines, D. J. Ziolkowski, Jr., K. L. Pardieck, J. E. Fallon, and W. A. Link.** 2017. The North American Breeding Bird Survey, Results and Analysis 1966–2015. Version 2.07.2017. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA. Accessed 10 March 2017. <https://www.mbr-pwrc.usgs.gov/bbs>.
- Schultz, C., and R. Levad.** 2001. Appendix B Black Swift Survey Protocol. USDA, Forest Service, San Juan National Forest, Bayfield, Colorado, USA. In D. Wiggins, 2004. Black Swift (*Cypseloides niger*): a technical conservation assessment. USDA Forest Service, Rocky Mountain Region. Accessed 27 March 2016 https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5182062.pdf.
- Tyson, D.** 2004. A Black Swift (*Cypseloides niger*) nest near Mission, B.C. *Discovery* (Vancouver Natural History Society) 33: 44–55.
- Wiggins, D.** 2004. Black Swift (*Cypseloides niger*): a technical conservation assessment. USDA Forest Service, Rocky Mountain Region. Accessed 27 March 2016. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5182062.pdf.
- Udvardy, M. D. F.** 1954. Summer movements of Black Swifts in relation to weather conditions. *Condor* 56: 261–267. <https://doi.org/10.2307/1364849>

Received 29 May 2016

Accepted 6 June 2017

Short-term Change in Forest Metrics at Grand Portage National Monument, Minnesota

SUZANNE SANDERS^{1, 2} and JESSICA KIRSCHBAUM¹

¹National Park Service, Great Lakes Inventory and Monitoring Network, 2800 Lake Shore Drive East, Ashland, Wisconsin 54806 USA

²Corresponding author: suzanne_sanders@nps.gov

Sanders, Suzanne, and Jessica Kirschbaum. 2017. Short-term change in forest metrics at Grand Portage National Monument, Minnesota. *Canadian Field-Naturalist* 131(2): 151–163. <https://doi.org/10.22621/cfn.v131i2.1986>

Forest health monitoring programs can provide routine feedback of key indices and periodic updates of ecosystem health. A forest monitoring program was initiated at Grand Portage National Monument in 2007 with plots resampled in 2014. Grand Portage National Monument is within the southern boreal forest and the suitable habitat for most of its common overstorey species is expected to shift northward and out of the park as climate change progresses. We assessed short-term change in forest health on 20 plots by specifically evaluating change in overstorey density and basal area, forest community composition, and White-tailed Deer (*Odocoileus virginianus*) browsing impacts on the herbaceous layer. Pooled across all overstorey species, both density and basal area increased between sampling events, but neither differed among habitats. For individual species of interest, responses were varied, although Balsam Fir (*Abies balsamea*) increased in both density and basal area over the seven years. The frequency of quadrats supporting at least one preferred browse species did not differ between sampling years although this was greater in upland plots (81%) compared with wet mesic sites (66%). The effect of sampling year on species' richness depended on habitat. In 2007, richness was higher in upland plots, although in 2014, richness was higher in wet mesic plots. Pooled across both sampling years, modified floristic quality index was greater in wet mesic plots. Our work demonstrates the increasing dominance of *A. balsamea* at Grand Portage National Monument and that notable differences in forest metrics can be observed over relatively short times.

Key Words: Boreal forest; browse ecological monitoring; forest change; Grand Portage National Monument; White-tailed Deer

Introduction

Forest health monitoring programs can provide information on the abundance and structure of individual species of interest (Duchesne *et al.* 2005; Fiedler and McKinney 2014), as well as the composition and integrity of plant communities as a whole (Steinman 2004; Auclair 2005). Provided they are designed properly, these monitoring programs can reveal relationships among biota such as herbivores and insect and fungal pests. Although parks and other natural areas are often designated as “unmanaged”, park personnel may be tasked with promoting healthy forests that would otherwise occur in the absence of ongoing anthropogenic influences. Actions such as reductions in herbivore abundance (Tanentzap *et al.* 2011), prescribed fire (Mutch and Parsons 1998), thinning as a fire surrogate (Schwilk *et al.* 2009), seedbed preparation (York *et al.* 2012), snag creation (Brandeis *et al.* 2002), and invasive species removal (Flory and Clay 2009) are all examples of active management within parks. Ongoing forest health monitoring programs are needed by land managers to evaluate if management interventions may be necessary to promote ecological integrity (Lutes *et al.* 2006; Apostle Island National Lakeshore 2014).

Grand Portage National Monument (GPNM; 47.9607°N, 89.6866°W) is a 287 ha tract in northeastern Minnesota, near the boundary of northern mixed temperate forests and southern boreal forests. This park

was established largely to commemorate the cultural legacy of the fur trade era and the native peoples of the region. It includes a 13.7 km foot path connecting Lake Superior with the Pigeon River, which serves as a portage trail, bypassing several major waterfalls on the lower reaches of the river. The park is surrounded by the Grand Portage Band of Lake Superior Chippewa reservation, a mosaic of forest and wetlands with large areas managed for timber.

Cultural resources at GPNM are tightly linked to natural resources, as both the fur traders and native peoples relied heavily on the forest. GPNM managers wish to promote species of cultural interest that are more resilient to impending climate-induced changes, thereby promoting both cultural and biological integrity. These species include Sugar Maple (*Acer saccharum* Marshall), Tamarack (*Larix laricina* (Du Roi) K. Koch), Red Pine (*Pinus resinosa* Aiton), Eastern White Pine (*Pinus strobus* L.), and both Trembling Aspen (*Populus tremuloides* Michaux) and Bigtooth Aspen (*Populus grandidentata* Michaux). These actions will aid in visitor interpretation of the fur trade, help maintain traditional uses of plants by the Ojibwa people, and restore the species composition of the forests to what was historically maintained via natural disturbance processes (National Park Service 2003).

Early settlement (prior to 1870) forest vegetation of GPNM varied along the trail. On the lower trail, nearer to Lake Superior, a matrix of *P. tremuloides*, Paper Birch

(*Betula papyrifera* Marshall), Yellow Birch (*Betula alleghaniensis* Britton), and mixed conifers were dominant, while further inland, *P. strobus* and *P. resinosa* were most common on the landscape (Marschner 1974). Park managers especially wish to promote the pine component, namely *P. strobus*, due to its historical dominance. The current structure and composition are largely a result of human-induced fires during and after European settlement (ca. 1870–1910), followed by decades of fire suppression (White and Host 2003). Two early successional species, *B. papyrifera* and *P. tremuloides*, are now prominent as scattered mature individuals amid large numbers of standing dead trees and downed boles. Gaps are largely filled with young Balsam Fir (*Abies balsamea* (L.) Mill.), along with dense Mountain Maple (*Acer spicatum* Lamarck) and Beaked Hazelnut (*Corylus cornuta* Marshall). In addition, selective foraging by both White-tailed Deer (*Odocoileus virginianus*) and Moose (*Alces americanus*) drive forest composition in the region (Pastor and Naiman 1992; White 2012). Deer browse heavily on *P. strobus* and Eastern White Cedar (*Thuja occidentalis* L.; White 2012) while *A. balsamea* is a preferred winter forage for Moose (De Jager and Pastor 2009). Both ungulates use a number of hardwood species during summer, limiting understorey development and initiating feedbacks with long-term consequences (Pastor and Naiman 1992; White 2012). Deer browse strongly impacts herbs by causing reductions in frequency (Balgooyen and Waller 1995) and loss of diversity (Rooney and Waller 2003).

The National Park Service (NPS) Great Lakes Inventory and Monitoring Network initiated a long-term monitoring program in 2007, at which time 20 permanent forest monitoring plots were established and sampled at GPNM. The overarching goal of this program is to conduct routine assessments of forest health by documenting the impacts of drivers (browse, climate change, etc.), stressors (pathogens, insect pests, precipitation, etc.), succession, and any other currently unforeseen impacts. These assessments will be used to guide forest management in the park. The initial 20 plots were resampled in 2014 and an additional three plots were established. Here we report on forest change from 2007–2014 to answer the following broad questions:

1) Have density or basal area of trees changed during the sampling interval? We posed this question first by including all species sampled, then by looking only at key species of interest, specifically: *A. balsamea*, *P. tremuloides*, *B. papyrifera*, *P. strobus*, and Black Ash (*Fraxinus nigra* Marshall).

2) How has ungulate browsing impacted GPNM forests? We tested for evidence of browse impacts on the herbaceous layer. Browsing herbs often consumes the entire above-ground portion. Rather than bite marks, herbaceous browse generally results in fewer and small-

er herbaceous species that are only indirectly evident over time. Therefore, we examined the collective frequency of eight preferred browse species, then also assessed height for two targeted taxa on which additional data were collected.

3) How has the plant community changed? We tested for differences in both species richness and the modified floristic quality index (mFQI; Rooney and Rogers 2002) between habitats and sampling events. The mFQI quantifies the degree of habitat faithfulness by species. Higher values indicate the presence of more specialist species, while lower values point to more generalists. We also used non-metric multidimensional scaling to see how plot locations shifted in ordination space during the seven-year sampling interval.

Study Area

GPNM is located within the Northern Superior Upland section (212L) of the Laurentian Mixed forest province (Ecoregion 212; Cleland *et al.* 1997). The mean July temperature high and low in Grand Portage during 1992–2014 were 23.3°C and 11.4°C, respectively. For January during that same period, the mean high and low were –6.2°C and –16.8°C, respectively. Mean annual precipitation from 1992–2014 was 75.4 cm with 44% falling from May through August (www.climateanalyzer.org).

GPNM is composed of a 13.7 km foot trail connecting Lake Superior with the Pigeon River; the park boundary provides a forested buffer of about 100 m on both sides of the trail for most of its length. At the Lake Superior terminus, a 28 ha tract of culturally maintained vegetation (mowed, garden, etc.) and historical buildings occupy the site. The Pigeon River trail terminus includes an expanded area of 44 ha, which is forested, with small openings for two primitive campsites. The Grand Portage Trail generally traverses high ground although several small streams cross it; moist pockets and forested wetlands are not uncommon within the buffer area on either side of the trail. A 2.1 ha American Beaver (*Castor canadensis*) pond is located along the trail, 9.4 km from the Lake Superior terminus.

Our sampling frame included all park lands except the Lake Superior tract, and the nearest 1.0 km of trail to the lake, because the park boundary here was only slightly wider than the trail itself.

Methods

Data collection and treatment

Sampling was conducted at GPNM during the summers of 2007 and 2014. Plot locations were chosen via a generalized random-tessellation stratified algorithm (Stevens and Olsen 2004), which ensured sites were randomly placed throughout the sampling frame, while also being spatially balanced. Specific details of the plot layout and field techniques are described by Sanders and Kirschbaum (2015), with an abbreviated version presented here.

To answer our first question, we recorded the diameter at breast height (DBH), species, and live/dead status for all trees ≥ 2.5 cm DBH, within the 900 m² tree sampling area of each plot (Figure 1).

Our second question addressed the impacts of ungulate browsing on herbaceous demography. These impacts are generally only indirectly observed over time as fewer and smaller individuals of preferred browse species (Webster *et al.* 2001; Kirschbaum and Anacker 2005), rather than as bite marks on individual plants. We used our personal knowledge to identify preferred browse species as those that are both relatively common in the region, and favoured by White-tailed Deer. While we are primarily interested in impacts by deer, browse from other herbivores was possible. Because

browsing by Moose on herbaceous plants is generally limited to aquatic species, and that on terrestrial species typically occurs on woody shrubs and small tree branches (Aho and Jordan 1976), we assumed that impacts on herbs due to Moose were minimal. In addition, regional Moose densities have remained low for the decade preceding this work (DelGiudice 2015). Snowshoe Hare (*Lepus americanus*), however, do browse many of the same herbaceous species as White-tailed Deer (Belovsky 1984; Rouleau *et al.* 2002; Frerker *et al.* 2013); attributing browse impacts to either mammal is only possible using supporting, ancillary data. The preferred browse species we identified were White Baneberry (*Actaea pachypoda* Elliott), Red Baneberry (*A. rubra* (Aiton) Willdenow), Wild Sarsaparilla (*Aralia*

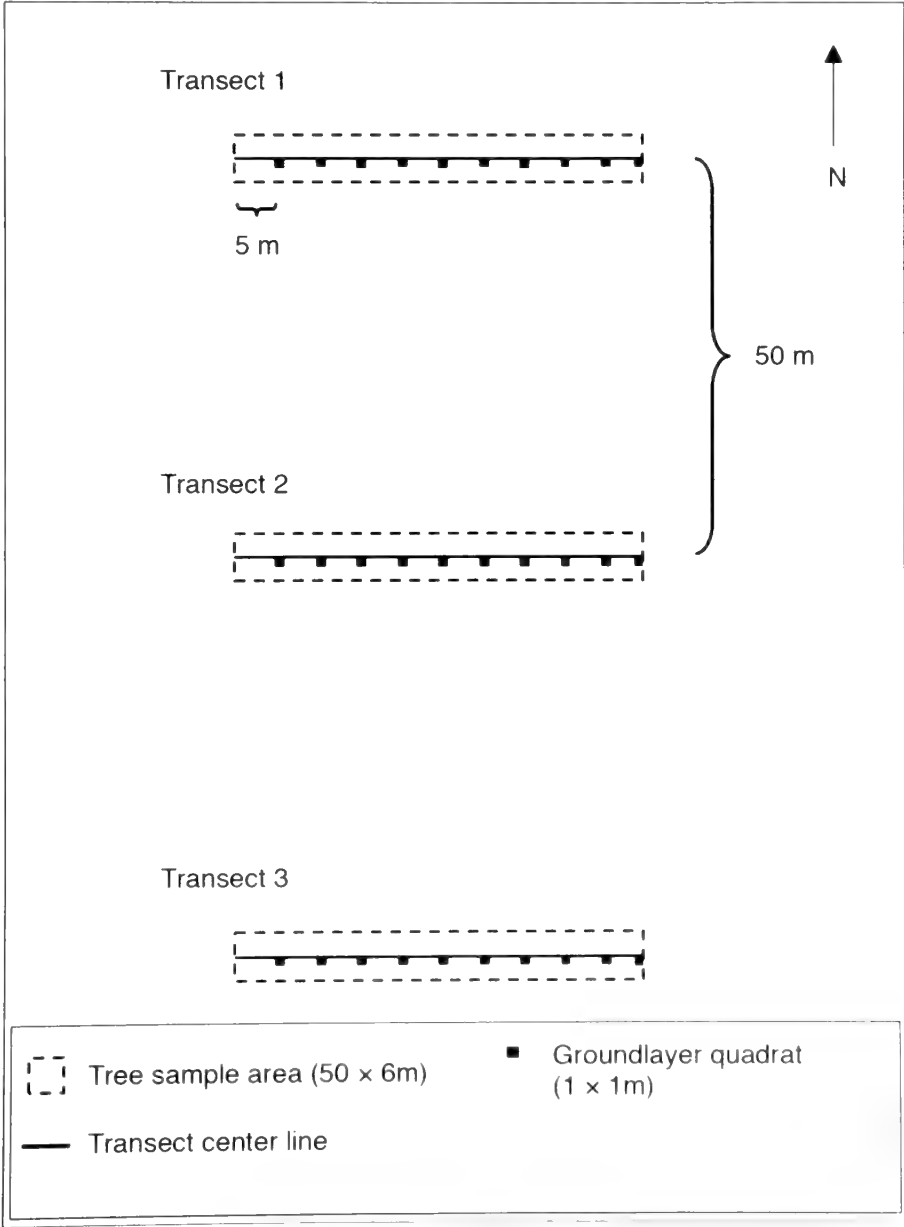


FIGURE 1. Plot layout, showing the three transects and 30 groundlayer quadrats. All data for herbaceous browse assessments were from the groundlayer quadrats.

nudicaulis L.), Bluebead Lily (*Clintonia borealis* (Aiton) Rafinesque), False Solomon's Seal (*Maianthemum racemosum* (L.) Link), Claspingleaved Twisted-stalk (*Streptopus amplexifolius* (L.)), Rosy Twisted-stalk (*S. lanceolatus* var. *roseus* (Michx.) Reveal), and Nodding Trillium (*Trillium cernuum* L.). As part of our sampling protocols, we recorded all herbaceous species present in each of 30, 1 m² quadrats throughout the plot (Figure 1). We then used the groundlayer data to look at presence frequency from which we pooled all preferred browse species and determined the frequency of quadrats within plots where at least one of these species was present. We also assessed indirect impacts of browse by measuring the tallest of two target taxa (*C. borealis* and *Streptopus* spp.) within each quadrat where they were present. For each taxon we then calculated maximum height as the mean value of the tallest individuals in the plot.

We assessed plant community (the focus of our third question) by supplementing quadrat-level data with that obtained in a 30 min time-delimited search of each plot. Any species not previously noted were recorded.

We identified all plants to species while in the field, to the extent possible. When this was not possible, we collected specimens for later identification. In some instances, however, a lack of reproductive parts allowed identification only to genus or family. Examples include sedge (*Carex* sp.), shinleaf (*Pyrola* sp.), and Poaceae (grass family). For serviceberry (*Amelanchier* sp.), a genus that presented notable identification challenges, we assigned individual plants to one of three groups of species complexes, with Group 1 containing *A. bartramiana*; Group 2 containing *A. arborea*, *A. laevis*, and *A. interior*; and Group 3 containing an uncertain number of species (Smith 2008). All nomenclature follows the Integrated Taxonomic Information System (ITIS 2014).

We grouped plots into similar types using cluster analysis. We constructed separate multivariate matrices based on abundance indices of both tree and groundlayer species within each plot. For the tree matrix, we calculated the importance value, determined by the mean of the relative density and relative basal area, for each species-plot combination (Dyer 2006; Elliott and Swank 2008). For the understorey (herb and shrub/woody vine) matrix, the abundance for each species-plot combination was determined by the proportion of groundlayer quadrats in which each species was located within that plot. For both trees and understorey, we limited inclusion in the cluster analysis to those taxa that were present in at least 8% (3 of 23) of the plots. For this analysis we used PC-ORD software (McCune and Grace 2002) and selected a Sørensen distance measure and a flexible beta linkage ($\beta = -0.25$). Habitat type names were assigned based on the dominant trees in these groups. We used non-metric multidimensional scaling (NMS) to verify the legitimacy of these groups, using PC-ORD.

We identified coefficient of conservatism (CoC) values for all species located during the sampling at GPNM. These values quantify the habitat faithfulness of species (Swink and Wilhelm 1994; Wilhelm and Masters 1995) and range from 0 (either non-native species or generalists with no faithfulness to any particular habitat) to 10 (conservative species found only within limited niches of certain non-degraded habitats). Because CoC values have not been assigned for terrestrial species in Minnesota, we used the values defined for Ontario (Oldham *et al.* 1995) for species present during our sampling. Two species, however, (Tea-leaved Willow [*Salix planifolia* Pursh] and Squashberry [*Viburnum edule* (Michaux) Rafinesque]) were not listed by Oldham *et al.* (1995), so we used CoC values assigned for wetland species in Minnesota (Milburn *et al.* 2007). We then used CoC values to calculate the modified floristic quality index (mFQI; Rooney and Rogers 2002; Sanders and Grochowski 2014) where mFQI is simply the mean of the CoC values for all species present within that plot.

Forest change analyses

To address our first question about forest change, we used two-way repeated measures analysis of variance (ANOVA) and tested whether density and basal area differed between sampling periods and between habitat types. We performed this analysis pooling all species, then individually for each key species of interest. For all two-way repeated measure ANOVA tests, two treatment effects (habitat and year) and their interaction (habitat \times year), were considered fixed effects; the plot (habitat) term, and its interaction with year, were considered random effects. We also tested whether total sapling density differed between sampling periods or habitats, using the same model. All ANOVA tests were conducted using JMP (v. 7; SAS Institute Inc., Cary, North Carolina, USA). Lastly, we compared the diameter-distribution of trees in 2007 with that in 2014, by carrying out the Kolmogorov-Smirnov test using the R statistical software package (R Core Team 2012).

Our second question focused on ungulate browsing impacts. We tested for change between 2007 and 2014 using two indirect browse indices: the frequency of quadrats in each plot supporting at least one preferred browse species (i.e., frequency of presence), and the mean plot height of preselected target taxa. Again, we used two-way repeated measures ANOVA and tested whether these indices differed between years and habitats, as well as tested their interaction term.

Our third question asked whether plant communities differed between the sampling periods; we answered this using a suite of approaches. We first tested whether plot-level species richness and the mFQI differed between years or habitats, using two-way repeated measures ANOVA. For all 20 plots that were resampled, we then used non-metric multi-dimensional scaling (NMS) (McCune and Grace 2002) to view the similarity of plots relative to each another, in ordinal space. We

applied vectors to denote the change in location of each plot between 2007 and 2014. Because we are assessing change in only a seven-year interval, we performed separate analyses for the overstorey (trees) and understorey (herbs and shrubs/woody vines). We felt the changes observed in the overstorey would largely be due to longer-term successional dynamics, while variation in the understorey would likely be in response to shorter-term impacts, including variation in browse pressure and precipitation. As with cluster analysis, the NMS was based on the importance value of trees for the overstorey analysis and the frequency of herbs and shrubs/woody vines for the understorey analysis. We limited our dataset to taxa with at least three occurrences over the two sampling events. We also eliminated data on plants only identified to *Carex* sp. and Poaceae due to the broad ecological width occupied by these groups. We used an automated procedure beginning with 250 runs of real data and 250 runs to evaluate stability. These resulted in solutions with a final stress of 8.67 in the overstorey dataset and 10.85 for the understorey data.

Results

Among all 23 plots, we identified 20 tree species, 31 shrub and woody vine taxa, and 148 taxa of herbs. Plots were classified as one of two habitat types: upland spruce-fir-aspen (18 plots) and wet mesic mixed conifer/hardwood (five plots).

Changes in density or basal area

Our first question addressed whether density and/or basal area changed between sampling intervals. For all species collectively, both total density ($F_{1,22} = 75.83$, $P < 0.0001$) and total basal area ($F_{1,22} = 4.90$, $P = 0.0400$) increased significantly between the two sampling periods, although neither differed between habitats (Figure 2), nor depended on the sampling period \times habitat interaction term.

We also tested if density and basal area are changing for key species of interest. *Abies balsamea* density and basal area depended on both year and habitat; both metrics were significantly greater in 2014 and in upland habitat (Table 1, Figure 3). Density of *P. tremuloides*

was significantly greater in 2014 (525 ± 35.5 [SE] trees/ha versus 232 ± 89.5 [SE] trees/ha in 2007), but did not differ significantly between habitats; *P. tremuloides* basal area did not differ significantly by habitat or year (Table 1). For *B. papyrifera*, neither metric differed significantly by habitat or year. Likewise, neither metric for *P. strobus* differed significantly on the year sampled; we could not test for differences between habitats due to inadequate sample size. *Fraxinus nigra* density did not differ significantly between years or habitats, although basal area tended toward being greater in 2007 (0.731 ± 0.309 [SE] m²/ha versus 0.603 ± 0.242 [SE] m²/ha in 2014; Table 1).

Across both habitat types, the density-diameter class distributions differed significantly between the sampling periods (Kolmogorov-Smirnov test; $P < 0.0001$; Figure 4).

Impacts of deer browsing

A test of the indirect impact of deer browsing on herb abundance showed that the frequency of quadrats supporting at least one preferred browse species did not differ between years ($F_{1,22} = 0.31$, $P = 0.5846$) although it tended to depend on habitat ($F_{1,22} = 4.06$, $P = 0.0572$). Across both years, 81% of quadrats in upland plots supported at least one preferred browse species, while only 66% of wet mesic sites did so. For *C. borealis*, mean height within plots was significantly greater among sampling years ($F_{1,15} = 5.17$, $P = 0.0344$) with a tendency for mean height to also differ between habitats ($F_{1,15} = 3.65$, $P = 0.0698$; Figure 5). Across both habitats, mean plot height of *C. borealis* was 12.4 ± 0.592 [SE] cm in 2007 and 13.2 ± 0.527 [SE] cm in 2014; across both years, mean height was 12.4 ± 0.439 [SE] cm in upland habitat and 14.4 ± 0.690 [SE] in wet mesic sites. *Streptopus* sp. height did not differ significantly between habitats ($F_{1,18} = 0.76$, $P = 0.3937$) or sampling years ($F_{1,18} = 2.69$, $P = 0.1183$).

Plant community composition

The effect of sampling year on mean plot species richness depended on habitat (i.e., significant interaction term, $F_{1,1} = 12.85$, $P = 0.0020$; Figure 6). In 2007, richness was higher in upland plots (61.2 ± 1.53 [SE]

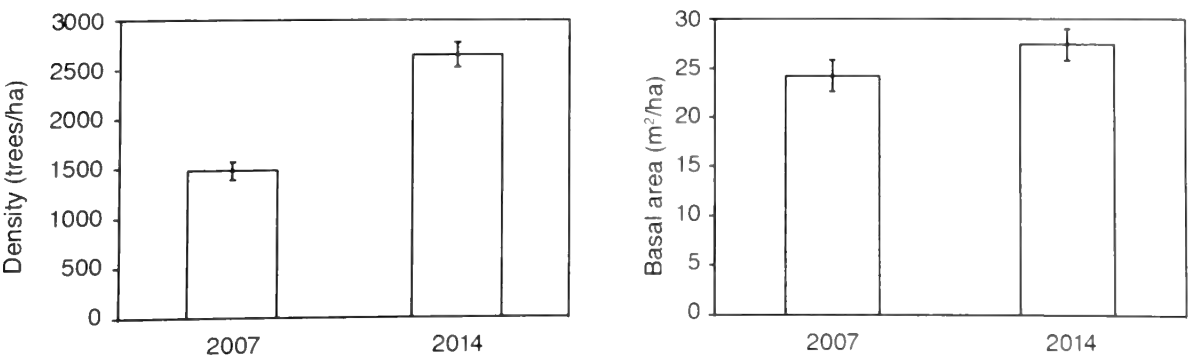


FIGURE 2. Density and basal area for live trees of all species in both 2007 and 2014. Results are pooled across both habitat types. Both indices were greater in 2014. Error bars reflect the standard error.

TABLE 1. ANOVA *P* values for density, basal area, and their interaction, of five key species of interest.

Species	Metric	Habitat	Year	Habitat × Year
Balsam Fir (<i>Abies balsamea</i>)	density	0.0161	<0.0001	0.7287
	basal area	0.0002	0.0034	0.1159
Trembling Aspen (<i>Populus tremuloides</i>)	density	0.0710	0.0002	0.1042
	basal area	0.9996	0.3461	0.1556
Yellow Birch (<i>Betula papyrifera</i>)	density	0.6964	0.2028	0.8989
	basal area	0.5271	0.6437	0.6258
White Pine (<i>Pinus strobus</i>)*	density		0.2053	
	basal area		0.1951	
Black Ash (<i>Fraxinus nigra</i>)	density	0.2209	0.0973	0.8342
	basal area	0.0856	0.0552	0.8931

*Inadequate sample size precluded tests of habitat and interactive effects on *Pinus strobus*.

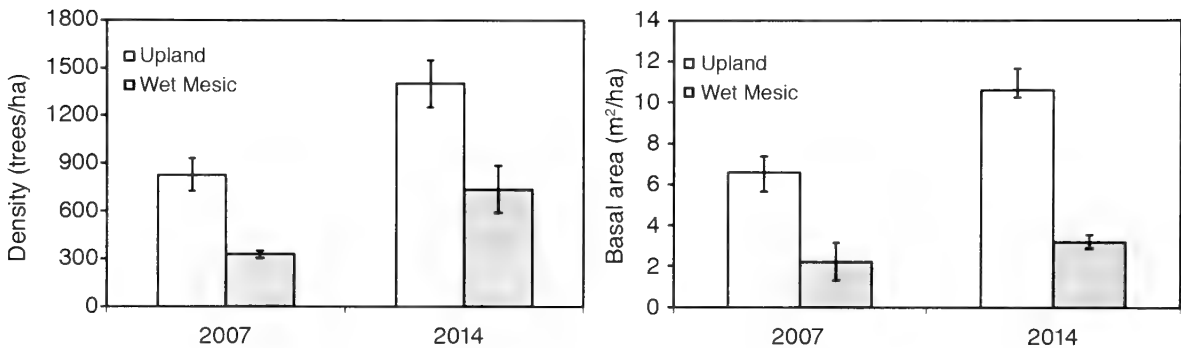


FIGURE 3. Density and basal area of Balsam Fir (*Abies balsamea*) in both habitats and years. Both metrics were greater in 2014 and in upland habitat. Error bars reflect the standard error.

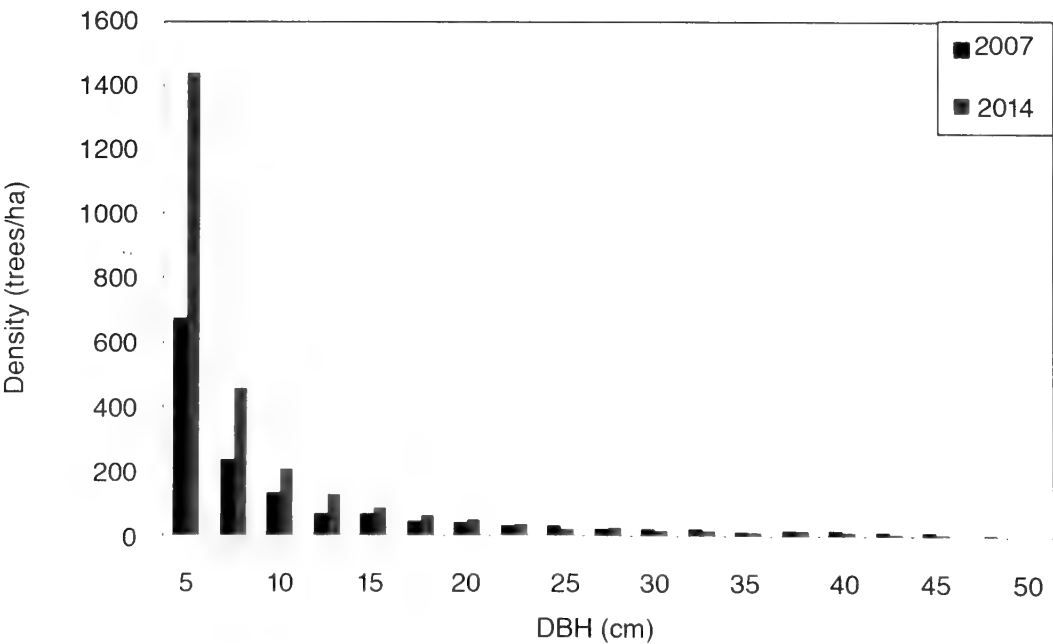


FIGURE 4. Density-diameter at breast height (DBH) distributions for trees differed between the two sampling periods. Results are pooled across both habitat types and included all species.

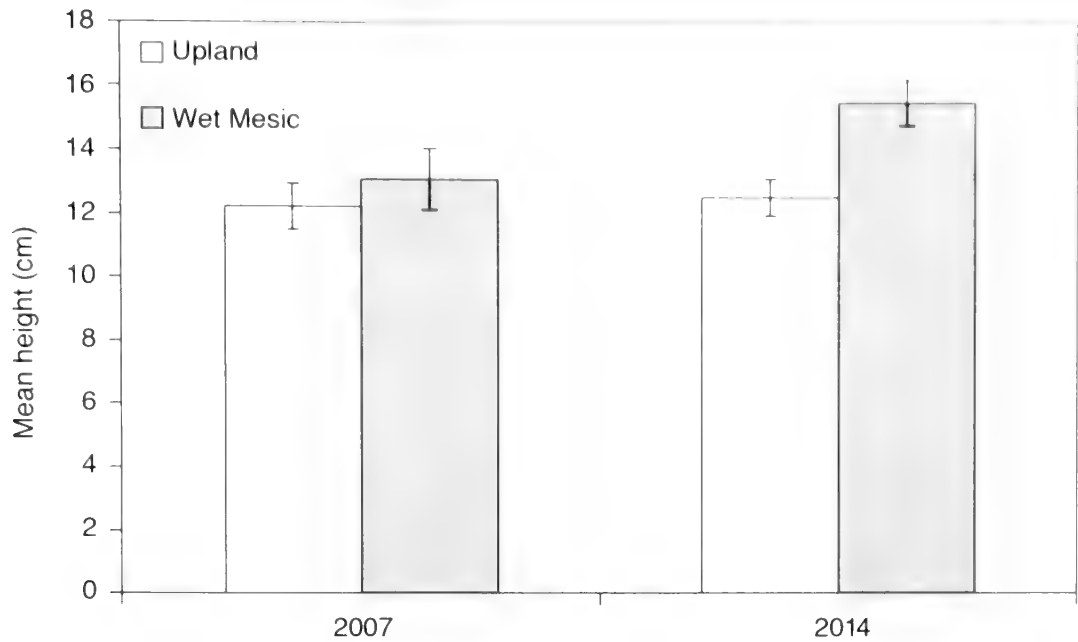


FIGURE 5. Height of Bluebead Lily (*Clintonia borealis*), a target preferred browse species, in both habitats and sampling periods. Height was greater in 2014 and tended toward being greater in wet mesic habitats. Error bars reflect the standard error.

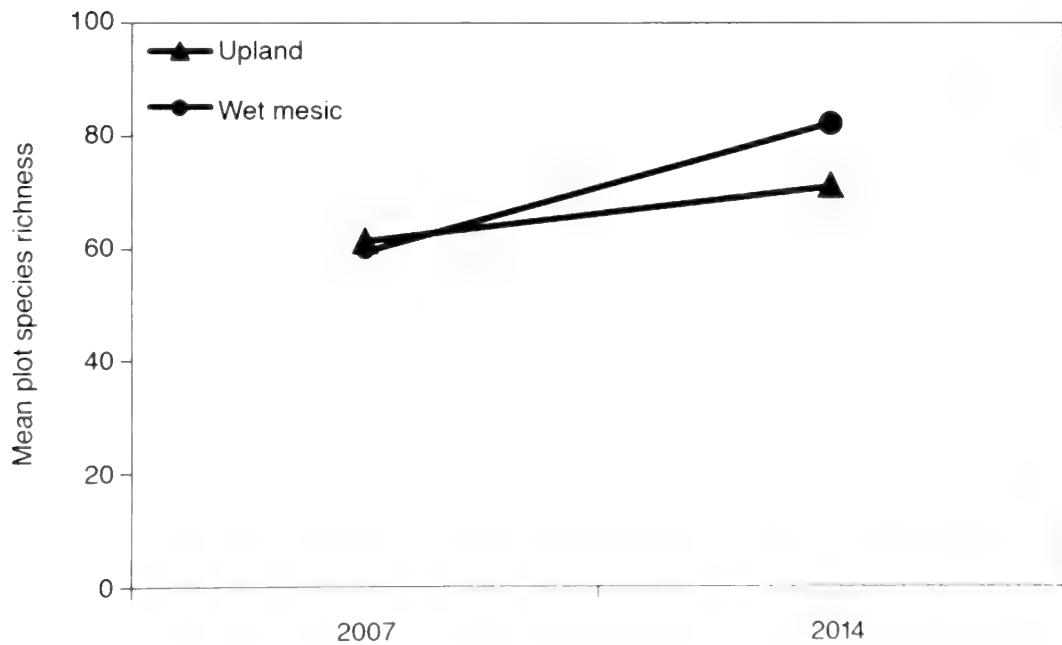


FIGURE 6. Mean plot species richness in both habitats and sampling periods.

versus 59.5 ± 2.02 [SE]), although in 2014, richness was higher in wet mesic plots (82.2 ± 3.5 [SE] versus 71 ± 2.3 [SE]).

The mFQI did not differ significantly between years ($F_{1,22} = 0.10$, $P = 0.7575$) although there was a trend toward significant difference between habitats ($F_{1,22} = 4.13$, $P = 0.0540$). Pooled across both sampling

years, mFQI was 4.88 ± 0.044 [SE] in upland plots and 5.08 ± 0.086 [SE] in wet mesic plots.

The NMS ordination results on overstorey data (Figure 7) support our other findings of marked increases in both *A. balsamea* and *P. tremuloides*. Vectors corresponding with increasing values of both Axes 1 and 2 (i.e., pointing toward the upper right) represent

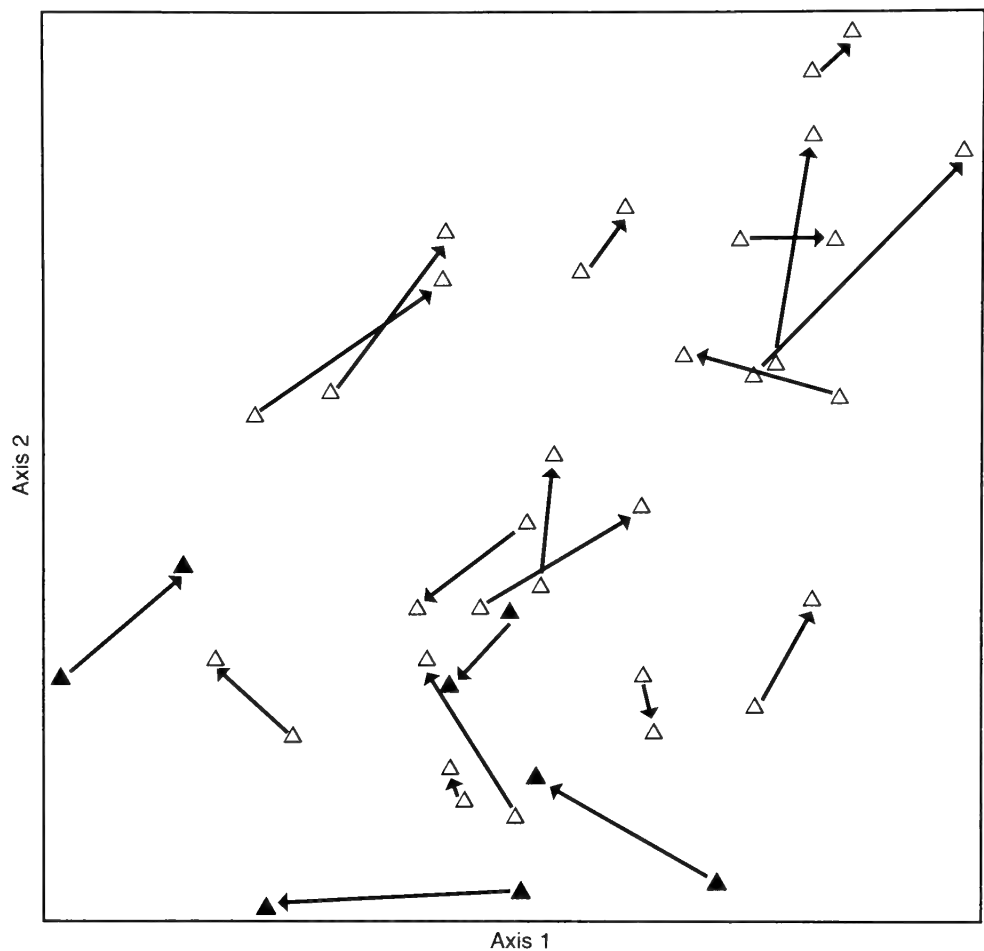


FIGURE 7. Nonmetric Multidimensional Scaling ordination of overstorey data with vectors drawn from the 2007 location to the 2014 location for each plot. Open triangles are plots in in upland habitat; solid triangles are plots in wet mesic habitat.

plots with large increases in density of *A. balsamea*. Those vectors pointing toward the upper left, representing decreasing values of Axis 1 and increasing values of Axis 2, correspond with plots with large density increases in both *A. balsamea* and *P. tremuloides*. The correlation coefficient (*r*) for each overstorey species on Axes 1 and 2 (Table 2) reflects this; low Axis 2 values

are also observed for *F. nigra* and *A. spicatum*, which experienced substantial ingrowth in a small handful of plots. The NMS Ordination on understorey abundance showed a strong directional pattern, with all plots increasing along Axis 2 (Figure 8). While this signal appeared particularly strong for a small number of herbs

TABLE 2. Nonmetric Multidimensional Scaling axis correlations for overstorey species present in at least three plots.

Species	Axis 1	Axis 2
White Pine (<i>Pinus strobus</i>)	-0.638	0.007
Trembling Aspen (<i>Populus tremuloides</i>)	-0.409	-0.429
Balsam Poplar (<i>Populus balsamifera</i>)	-0.363	-0.288
White Spruce (<i>Picea glauca</i>)	-0.323	0.116
Black Ash (<i>Fraxinus nigra</i>)	-0.310	-0.520
White Cedar (<i>Thuja occidentalis</i>)	-0.310	-0.340
Bebb Willow (<i>Salix bebbiana</i>)	-0.191	0.088
Mountain Maple (<i>Acer spicatum</i>)	-0.116	-0.603
Choke Cherry (<i>Prunus virginiana</i>)	-0.014	-0.012
Mountain Ash (<i>Sorbus decora</i>)	-0.013	0.157
Sugar Maple (<i>Acer saccharum</i>)	0.145	0.191
Black Ash (<i>Picea mariana</i>)	0.177	-0.059
Paper Birch (<i>Betula papyrifera</i>)	0.267	-0.421
Balsam Fir (<i>Abies balsamea</i>)	0.756	0.913

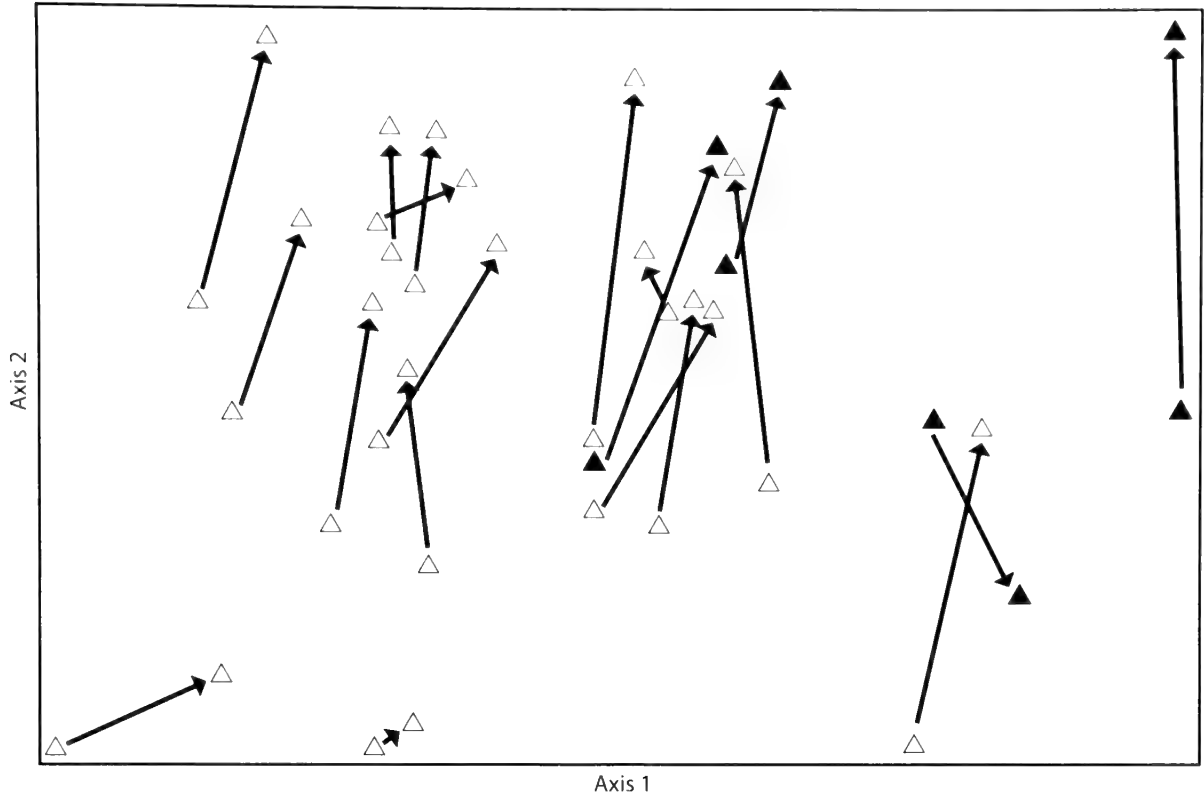


FIGURE 8. Nonmetric Multidimensional Scaling ordination of herbaceous and shrub data with vectors drawn from the 2007 location to the 2014 location for each plot. Open triangles are plots in upland habitat; solid triangles are plots in wet mesic habitat.

(including Wood Anemone [*Anemone quinquefolia* L.] and Bunchberry [*Cornus canadensis* L.]) the directional pattern was also present in those plots where decreases in these species were observed.

Discussion

Our results of overstorey change observed over the seven-year sampling interval mirror those of other studies throughout the region (Friedman and Reich 2005; Frelich and Reich 2009a). Early successional hardwoods, which were established at the time of stand initiation, have aged and shade tolerant species dominated by *A. balsamea* became established. As most stands are now nearing or beyond 100 years old, those early successional species, dominated by *P. tremuloides*, are being killed by a mix of factors, including windthrow, root disease, Forest Tent Caterpillar (*Malacosoma disstria*), and drought. The gap-phase forest is now a mosaic of young *A. balsamea*, with *A. spicatum* and clones of *P. tremuloides* colonizing the gaps. Our observation of dual high density of both *A. balsamea* and *P. tremuloides* is somewhat unusual because they generally occur on opposite ends of the successional spectrum. As stands aged, *A. balsamea* gradually became established under the *P. tremuloides* canopy; subsequent losses of individuals from the oldest *P. tremuloides* cohort, composed of trees typically > 30 cm diameter, most likely promoted root suckering and adventitious shoot

growth of clones, in response to the loss of apical dominance (Wan *et al.* 2006). High density of both of these species is not commonly observed in managed forests because harvest of early successional species often occurs before later-successional species become well established.

Pinus strobus, while historically common, now exists at low densities across the landscape; an arrangement that limits the spatial extent of seed rain which, in turn, hinders regeneration. In the absence of fire, *A. balsamea* dominance will likely increase as other species adapted to fire become less prominent. One possible check on *A. balsamea* dominance, however, is a future outbreak of Spruce Budworm (*Choristoneura fumiferana*), a native species that attacks spruce, fir, and several other genera of conifer. An infestation in spruce-fir stands in Minnesota in the 1970s resulted in a reduction in stand basal area from 79% to 31% of the total (Batzler and Popp 1985).

Precipitation differences between the two sampling years may explain the patterns observed in understorey plant communities. Precipitation during the mean growing season (May–August) from 1992 to 2014 was 33.5 cm (Climate Analyzer 2015). The 2007 sampling occurred during a relatively dry period with 24.5 cm and 17.4 cm of precipitation during the 2006 and 2007 growing seasons, respectively. The climate was wetter during the later sampling when mean growing season

precipitation totalled 39.0 cm in 2013 and 41.3 cm in 2014. In 2014, wet mesic sites supported 11.2 more species than upland sites while in 2007, a dry year, wet mesic sites support 1.7 fewer species. It is possible that species adapted to more moist areas may have been reduced in abundance by more competitive generalists. Specialist species, by definition, will have higher coefficients of conservatism. Greater mFQI in wet mesic sites, relative to upland sites is therefore, not surprising.

The lower frequency of preferred browse species in wet mesic plots relative to upland sites suggests these areas with wet pockets constitute poorer habitat for our target species. Throughout the wet mesic plots were patches of Bluejoint (*Calamagrostis canadensis* (Michx.) P. Beauv.), Spotted Touch-me-not (*Impatiens capensis* Meerburgh), and Common Lady Fern (*Athyrium filix-femina* (L.) Roth). While we observed only a minimal amount of standing water at these sites during our sampling, these species suggest the presence of water was greater in the spring, likely limiting the areas where target species occur. Our finding of a trend that *C. borealis* was taller in wet mesic sites could suggest that browse pressure may be reduced here, although we did not find this with our other target species, *S. lanceolatus* var. *roseus*. In future sampling, we will measure height of three target species allowing for a fuller assessment of browse impacts on herb height.

The findings presented here for browse should not be interpreted too robustly. In general, neither deer, nor hare browsing pressure is currently high in the area. While White-tailed Deer abundance has increased over the previous decade on the Grand Portage Reservation, the density is still relatively low. Winter helicopter surveys counted 56 White-tailed Deer in 2007 and 205 White-tailed Deer in 2014 over the 193 km² reservation land base (E. Isaac, personal communication). Conservatively, these would correspond to spring densities of 0.29 and 1.08 deer/km², respectively. These values are low compared with both current densities throughout the Upper Midwest Region (Rooney and Waller 2003) and with pre-European settlement estimates of 2–4 deer/km² in deciduous and mixed deciduous-conifer forests of the region (Alverson *et al.* 1988). As such, the current White-tailed Deer density is not likely to suppress regeneration of these herbs. Deer densities are low due to deep winter snow accumulation in northeast Minnesota (Nelson 1995). As climate change progresses, and winter snow loads decrease, our data from 2007 and 2014 can be used to assess any changes in browsing impacts to vegetation.

Snowshoe Hare impacts are less clear. Hare densities peak then crash on a 10-year cycle driven largely by the interacting effects of predation and food availability (Krebs *et al.* 2001). While the herbaceous dietary preferences of hare are similar to those of deer (Belovsky 1984; Rouleau *et al.* 2002; Frerker *et al.* 2013), Wolff (1978) showed that herbs composed about 50% of the diet of hare in central Alaska only during the month

of May, while in April and in the summer, herbs represented only about 10% of the hare diet. In northern Minnesota, Snowshoe Hare density peaked in 2011 with nearly 5 hares/100 km of survey line (Erb 2014); hare densities at the time of both of our sampling events (2007 and 2014) were at the cycle mid-point, half way between the high and low. We are unaware of any work quantifying the relationship between hare abundance and impacts to the herbaceous layer.

The differences observed in this study between sampling events for the overstorey, and especially for the herbaceous layer were somewhat surprising, given the short time interval between them. Obviously, the different time between sampling dates for the 2007 (8 June – 19 July) and 2014 (22 June – 19 August) event could contribute to this, although we feel would only be a minor factor, if any at all. The latest-emerging species at GPNM are the July-flowering asters that were observed (pre-flowering) during our training period in early June. Conversely, the taxa which typically exhibit the earliest sign of senescence in the park are Starflower (*Trientalis borealis* Rafinesque) and various fern species. Although chlorosis was evident during the final week of sampling in 2014, they were still distinctive, and were easily identified throughout the park, at least through the final sampling day. The degree to which our observed differences reflect true directional change versus simply a response to stochastic year-to-year variation is unclear. Dynamics such as deer abundance (and hence, browsing), precipitation, and severe wind can vary highly between years leading to large differences between closely-timed sampling events. Analyses of vegetation change are often opportunistic resampling events on the order of 50 years (Jones *et al.* 1994; Johnson *et al.* 2014), rather than shorter-term studies with planned revisit schedules and pre-identified questions (for an exception, see Taverna *et al.* [2005]). Interpretation of results of these long-term studies may warrant a brief discussion on the drivers and stressors that may be acting on the systems near the time of both the initial and follow-up sampling events. For this current project, we are scheduled to sample a third time in 2024 with repeated sampling approximately every 9–10 years. This should allow us to parse out long-term trends versus shorter term variability.

Management and Climate Change

While our work follows convention by using traditional statistical approaches to test for change, we caution against a strict interpretation. Forests may be in the early stages of displaying climate change-induced shifts and managers need to recognize these changes, whether statistically significant or not. GPNM is situated at the boundary between the boreal forest to the north and Laurentian mixed forest to the south. As such, many boreal species present in the park are near their southern range limits; favourable habitat conditions for their reproduction and growth are predicted to migrate north-

ward and out of the region (Frelich and Reich 2009a). In their stead, the growing conditions are expected to become more favourable for oaks (*Quercus* spp.) and pines (*Pinus* spp.; Frelich and Reich 2009b). It is currently unclear, however, whether the migration rates of these groups can keep pace with the migration rate of their climate envelope (Frelich and Reich 2009a).

Climate change resilience strategies focus on promoting the growth of species expected to remain in the area, while minimizing the spread of newly arriving invasive species. Park managers have implemented a project to promote *P. strobus* regeneration within the park by outplanting for seed rain restoration, releasing advance regeneration, and also manually controlling *A. balsamea*. This project encourages current regeneration of *P. strobus* so that seed sources may be available for future regeneration once *A. balsamea* begins to die out. Managers may also wish to promote the growth of other species expected to remain in the area, including *B. papyrifera* and *T. occidentalis*. While the former species is often early successional, the latter can be slow-growing and long-lived (Fowells 1965). Germination and seedling growth of *T. occidentalis* preferentially occurs under a *Thuja* canopy (Cornett *et al.* 1997) and on coarse wood substrates (Cornett *et al.* 2001); because of this feedback, maintaining and promoting existing populations and coarse woody structures should be a priority. Indeed, long-term goals of the park include promoting conifer cover in riparian corridors, in conjunction with *T. occidentalis* seed rain. This may create a feedback loop by promoting greater moisture and shading, and hence providing refugia for southern boreal conifers.

While climate change is an important concern to the park, a more immediate concern to park managers is the arrival of Emerald Ash Borer (*Agrilus planipennis*). As of spring 2015, this exotic insect is now established in Duluth, Minnesota, approximately 233 km to the southwest of GPNM. *Fraxinus nigra* was located in 16 of the 23 plots; most of these plots were located in the half of the trail closer to Pigeon River. None were in the nearest 3 km to Lake Superior. In areas where we observed *F. nigra*, we also commonly observed populations of Speckled Alder (*Alnus incana* subsp. *rugosa* (Du Roi) R.T. Clausen) with smaller inclusions of Green Alder (*Alnus viridis* subsp. *crispa* (Aiton) Turritt). It is likely that populations of these species of alder will expand and fill niches left vacant by ash trees once Emerald Ash Borer arrives and ash trees begin to succumb to it.

Broader Relevance

While our work is limited to GMNP, its relevance extends throughout northern Minnesota. This region is heavily forested, and includes a state forest, numerous state parks, and the Superior National Forest. The latter encompasses the 441 000 ha Boundary Waters Canoe Area Wilderness and is adjacent to the 460 000 ha Quetico Provincial Park in Ontario. Both of these areas

are largely unmanaged and are subject to the same pressures as GPNM. Our results demonstrate what can happen in the absence of fire; they can be used by managers of these other areas as one part of a decision tool, where prescribed fire is a valid option.

Perhaps the most relevant aspect of our work may also be in advancing efforts to assess browsing by deer, particularly in the summer and/or on herbaceous species. While the deer population is not currently high at GPNM, high deer densities elsewhere in the northern Great Lakes Region are the norm (Rooney and Waller 2003). Deer browsing is driving regional species loss and homogenization in forests (Li and Waller 2015), and there is great interest in developing methods to assess its impacts. There is also growing recognition that assessing herbaceous browse by bite marks is of limited value because deer frequently consume entire plants. While our specific methods may not necessarily fit the monitoring protocols of others, our work shows how monitoring for change over time in the frequencies of understorey species can be used to monitor impacts by deer browsing.

Much of northern Minnesota is heavily forested. With Lake Superior to the east, and grasslands to the west, this region may emerge as a corridor through which species migrate northward and northeastward as temperatures warm and associated climate change continues. Because of the key biogeographic role that the forests of northern Minnesota may play in the future, we need to learn about current, shorter-term vegetation dynamics. Regeneration successes and failures, browsing impacts, and species' competitive abilities will likely all weigh heavily on forest management decisions in the region over the next 50 years. Our work here may serve as one resource that managers draw on as they face these decisions.

Acknowledgements

Major funding was provided by the National Park Service, Inventory and Monitoring Division. Additional funding was provided by Anthony D'Amato and the University of Minnesota. We are grateful for the vegetation monitoring field crew of Christine Groebner and Kaylee Nelsen. Without their assistance, this project would not have been possible. We are also indebted to Brandon Seitz, Bill Clayton, and many others on staff at the Grand Portage National Monument for planning, logistical, and administrative assistance. We wish to thank Edmund Isaac of the Grand Portage Band of the Minnesota Chippewa for providing deer density estimates (14 October 2015). Finally, we greatly appreciate Anthony D'Amato, Brandon Seitz, Mark White, Rolf Peterson, and two anonymous reviewers for providing reviews of earlier drafts of this manuscript.

Literature Cited

Aho, R. W., and P. A. Jordan. 1976. Production of aquatic macrophytes and its utilization by moose on Isle Royale National Park. Pages 341–348 in Proceedings of the First

- Conference on Scientific Research in the National Parks. U.S. Department of the Interior, New Orleans, Louisiana, USA.
- Alverson, W. S., D. M. Waller, and S. L. Solheim.** 1988. Forests too deer: edge effects in northern Wisconsin. *Conservation Biology* 2: 348–358. <https://doi.org/10.1111/j.1523-1739.1988.tb00199.x>
- Apostle Islands National Lakeshore.** 2014. Harvestable species plan: Apostle Islands National Lakeshore. Bayfield, Wisconsin, USA. Accessed 28 June 2017. <https://www.nps.gov/apis/learn/management/upload/CURRENT-Harvestable-Species-Plan-w-out-EA-4-14.pdf>.
- Auclair, A. N. D.** 2005. Patterns and general characteristics of severe forest dieback from 1950–1995 in the northeastern United States. *Canadian Journal of Forest Research* 35: 1342–1355. <https://doi.org/10.1139/x05-066>
- Balgooyen, C. P., and D. M. Waller.** 1995. The use of *Clin-tonia borealis* and other indicators to gauge impacts of white-tailed deer on plant communities in northern Wisconsin, USA. *Natural Areas Journal* 15: 308–318.
- Batzer, H. O., and M. P. Popp.** 1985. Forest succession following a spruce budworm outbreak in Minnesota. *The Forestry Chronicle* 61: 75–80. <https://doi.org/10.5558/tfc61075-2>
- Belovsky, G. E.** 1984. Snowshoe hare optimal foraging and its implications for population dynamics. *Theoretical Population Biology* 25: 235–264. [https://doi.org/10.1016/0040-5809\(84\)90009-1](https://doi.org/10.1016/0040-5809(84)90009-1)
- Brandeis, T. J., M. Newton, G. M. Filip, and E. C. Cole.** 2002. Cavity-nester habitat development in artificially made Douglas-fir snags. *Journal of Wildlife Management* 66: 625–633. <https://doi.org/10.2307/3803129>
- Cleland, D. T., P. E. Avers, W. H. McNab, M. E. Jensen, R. G. Bailey, T. King, and W. E. Russell.** 1997. National hierarchical framework of ecological units. Pages 181–200 in *Ecosystem Management Applications for Sustainable Forest and Wildlife Resources*. Edited by M. S. Boyce and A. Haney. Yale University Press, New Haven, Connecticut, USA.
- Climate Analyzer.** 2015. Climate data online. Walking Shadow Ecology, Gardner, Montana, USA. Accessed 29 July 2015. http://www.climateanalyzer.org/glkn/grand_portage.
- Cornett, M. W., P. B. Reich, and K. J. Puettmann.** 1997. Canopy feedbacks and microtopography regulate conifer seedling distribution in two Minnesota conifer-deciduous forests. *Écoscience* 4: 353–364. <http://dx.doi.org/10.1080/11956860.1997.11682414>
- Cornett, M. W., K. J. Puettmann, L. E. Frelich, and P. B. Reich.** 2001. Comparing the importance of seedbed and canopy type in the restoration of upland *Thuja occidentalis* forests of northeastern Minnesota. *Restoration Ecology* 9: 386–396. <http://dx.doi.org/10.1046/j.1526-100X.2001.94008.x>
- De Jager, N. R., and J. Pastor.** 2009. Declines in moose population density at Isle Royale National Park, MI, USA and accompanied changes in landscape patterns. *Landscape Ecology* 24: 1389–1403. <http://dx.doi.org/10.1007/s10980-009-9390-4>
- DelGiudice, G. D.** 2015. 2015 Aerial moose survey. Report to the Minnesota Department of Natural Resources. Minnesota Department of Natural Resources, St. Paul, Minnesota, USA.
- Duchesne, L., R. Ouimet, J.-D. Moore, and R. Paquin.** 2005. Changes in structure and composition of maple-beech stands following sugar maple decline in Québec, Canada. *Forest Ecology and Management* 208: 223–236. <https://doi.org/10.1016/j.foreco.2004.12.003>
- Dyer, J. M.** 2006. Revisiting the deciduous forests of eastern North America. *BioScience* 56: 341–352. [https://doi.org/10.1641/0006-3568\(2006\)56\[341:RTDFOE\]2.0.CO;2](https://doi.org/10.1641/0006-3568(2006)56[341:RTDFOE]2.0.CO;2)
- Elliott, K. J., and W. T. Swank.** 2008. Long-term changes in forest composition and diversity following early logging (1919–1923) and the decline of American chestnut (*Cas-tanea dentata*). *Plant Ecology* 197: 155–172. <https://doi.org/10.1007/s11258-007-9352-3>
- Erb, J.** 2014. Furbearer winter track survey summary, 2014. Report from the Forest Wildlife Populations and Research Group, Minnesota Department of Natural Resources, Grand Rapids, Minnesota, USA.
- Fiedler, C. E., and S. T. McKinney.** 2014. Forest structure, health, and mortality in two Rocky Mountain whitebark pine ecosystems: implications for restoration. *Natural Areas Journal* 34: 290–299. <https://doi.org/10.3375/043.034.0305>
- Flory, S. L., and K. Clay.** 2009. Invasive plant removal method determines native plant community responses. *Journal of Applied Ecology* 46: 434–442. <https://doi.org/10.1111/j.1365-2664.2009.01610.x>
- Fowells, H. A.** 1965. Silvics of forest trees of the United States. U.S. Department of Agriculture, Agriculture Handbook 271. Washington, DC, USA.
- Frelich, L. E., and P. B. Reich.** 2009a. Wilderness conservation in an era of global warming and invasive species: a case study from Minnesota's Boundary Waters Canoe Area Wilderness. *Natural Areas Journal* 29: 385–393. <https://doi.org/10.3375/043.029.0405>
- Frelich, L. E., and P. B. Reich.** 2009b. Will environmental changes reinforce the impact of global warming on the prairie-forest border of central North America? *Frontiers in Ecology and the Environment* 8: 371–378. <https://doi.org/10.1890/080191>
- Frerker, K., G. Sonnier, and D. M. Waller.** 2013. Browsing rates and ratios provide reliable indices of ungulate impacts on forest plant communities. *Forest Ecology and Management* 291: 55–64. <https://doi.org/10.1016/j.foreco.2012.11.041>
- Friedman, S. K., and P. B. Reich.** 2005. Regional legacies of logging: departure from presettlement forest conditions in northern Minnesota. *Ecological Applications* 15: 726–744. <https://doi.org/10.1890/04-0748>
- ITIS (Integrated Taxonomic Information System).** 2014. ITIS online database. Accessed 2 February 2015. <http://www.itis.gov>.
- Johnson, S. E., E. L. Mudrak, and D. M. Waller.** 2014. Local increases in diversity accompany community homogenization in floodplain forest understories. *Journal of Vegetation Science* 25: 885–896. <https://doi.org/10.1111/jvs.12147>
- Jones, R., R. R. Sharitz, P. M. Dixon, D. S. Segal, and R. L. Schneider.** 1994. Woody plant regeneration in four floodplain forests. *Ecological Monographs* 64: 345–367. <https://doi.org/10.2307/2937166>
- Kirschbaum, C. D., and B. L. Anacker.** 2005. The utility of *Trillium* and *Maianthemum* as phyto-indicators of deer impact in northwestern Pennsylvania, USA. *Forest Ecology and Management* 217: 54–66. <https://doi.org/10.1016/j.foreco.2005.05.001>
- Krebs, C. J., R. Boonstra, S. Boutin, and A. R. E. Sinclair.** 2001. What drives the 10-year cycle of snowshoe hares? *BioScience* 35: 25–35. [https://doi.org/10.1641/0006-3568\(2001\)051\[0025:WDTYCO\]2.0.CO;2](https://doi.org/10.1641/0006-3568(2001)051[0025:WDTYCO]2.0.CO;2)

- Li, D., and D. M. Waller. 2015. Drivers of observed biotic homogenization in pine barrens of central Wisconsin. *Ecology* 96: 1030–1041. <https://doi.org/10.1890/14-0893.1>
- Lutes, D. C., R. E. Keane, J. F. Caratti, C. H. Key, N. C. Benson, S. Sutherland, and L. J. Gangi. 2006. FIRE-MON: fire effects monitoring and inventory system. General Technical Report RMRS-GTR-164-CD. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado, USA.
- Marschner, F. J. 1974. The original vegetation of Minnesota, a map compiled in 1930 by F. J. Marschner under the direction of M. L. Heinselman of the US Forest Service. St. Paul, Minnesota, USA.
- McCune, B., and J. B. Grace. 2002. Analysis of Ecological Communities. MjM software, P.O. Box 129, Gleneden Beach, Oregon, USA.
- Milburn, S. A., M. Bourdaghs, and J. J. Husveth. 2007. Floristic Quality Assessment for Minnesota Wetlands. Minnesota Pollution Control Agency, St. Paul, Minnesota, USA.
- Mutch, L. S., and D. J. Parsons. 1998. Mixed conifer forest mortality and establishment before and after prescribed fire in Sequoia National Park, California. *Forest Science* 44: 341–355.
- National Park Service. 2003. Grand Portage National Monument, final general management plan and environmental impact statement. Denver Service Center, Denver, Colorado, USA.
- Nelson, M. E. 1995. Winter range arrival and departure of white-tailed deer in northeastern Minnesota. *Canadian Journal of Zoology* 73: 1069–1076. <https://doi.org/10.1139/z95-127>
- Oldham, M. J., W. D. Bakowski, and D. L. Sutherland. 1995. Floristic quality assessment system for southern Ontario. Natural Heritage Information Centre, Ontario Ministry of Natural Resources, Peterborough, Ontario, Canada.
- Pastor, J., and R. J. Naiman. 1992. Selective foraging and ecosystem processes in boreal forests. *The American Naturalist* 139: 690–705. <https://doi.org/10.1086/285353>
- R Core Team. 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
- Rooney, T. P., and D. A. Rogers. 2002. The modified floristic quality index. *Natural Areas Journal* 22: 340–344.
- Rooney, T. P., and D. M. Waller. 2003. Direct and indirect effects of white-tailed deer in forest ecosystems. *Forest Ecology and Management* 181: 165–176. [https://doi.org/10.1016/S0378-1127\(03\)00130-0](https://doi.org/10.1016/S0378-1127(03)00130-0)
- Rouleau, L., M. Crête, G. Daigle, P. Etcheverry, and C. Beaudoin. 2002. Rapid estimation of plant biomass used as forage or cover by white-tailed deer, *Odocoileus virginianus*, and snowshoe hare, *Lepus americanus*, in mixed and coniferous forests of Southeastern Québec. *Canadian Field-Naturalist* 116: 523–528.
- Sanders, S., and J. Grochowski. 2014. Alternative metrics for evaluating forest integrity and assessing change at four northern-tier U.S. National Parks. *American Midland Naturalist* 171: 185–203. <https://doi.org/10.1674/0003-0031-171.2.185>
- Sanders, S., and J. Kirschbaum. 2015. Forest health monitoring on the St. Croix National Scenic Riverway: short-term change and longer-term projections. *Journal of the Torrey Botanical Society* 142: 271–282. <https://doi.org/10.3159/TORREY-D-14-00058.1>
- Schwilke, D. W., J. E. Keeley, E. E. Knapp, J. McIver, J. D. Bailey, C. J. Fetting, C. E. Fiedler, R. J. Harrod, J. J. Moghaddas, K. W. Outcalt, C. N. Skinner, S. L. Stephens, T. A. Waldrop, D. A. Yaussy, and A. Youngblood. 2009. The national fire and fire surrogate study: effects of fuel reduction methods on forest vegetation structure and fuels. *Ecological Applications* 19: 285–304. <https://doi.org/10.1890/07-1747.1>
- Smith, W. R. 2008. Trees and Shrubs of Minnesota. University of Minnesota Press, Minneapolis, Minnesota, USA.
- Steinman, J. 2004. Forest health monitoring in the northeastern United States: disturbances and conditions during 1993–2002. NA-TP-01-04, USDA Forest Service, Northern Research Station, Newton Square, Pennsylvania, USA.
- Stevens, D. L., Jr., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. *Journal of the American Statistical Association* 99: 262–278. <https://doi.org/10.1198/016214504000000250>
- Swink, F., and G. Wilhelm. 1994. Plants of the Chicago Region, Fourth Edition. The Indiana Academy of Science, Indianapolis, Indiana, USA.
- Tanentzap, A. J., D. R. Bazely, S. Koh, M. Timciska, E. G. Haggith, T. J. Carleton, and D. A. Coomes. 2011. Seeing the forest for the deer: do reductions in deer-disturbance lead to forest recovery? *Biological Conservation* 144: 376–382. <https://doi.org/10.1016/j.biocon.2010.09.015>
- Taverna, K., R. K. Peet, and L. C. Phillips. 2005. Long-term change in ground-layer vegetation of deciduous forests of the North Carolina piedmont, USA. *Journal of Ecology* 93: 202–213. <https://doi.org/10.1111/j.0022-0477.2004.00965.x>
- Wan, X., S. M. Landhäusser, V. J. Loeffers, and J. J. Zwiazek. 2006. Signals controlling root suckering and adventitious shoot formation in aspen (*Populus tremuloides*). *Tree Physiology* 26: 681–687. <https://doi.org/10.1093/treephys/26.5.681>
- Webster, C. R., M. A. Jenkins, and G. R. Parker. 2001. A field test of herbaceous plant indicators of deer browsing intensity in mesic hardwood forests of Indiana, USA. *Natural Areas Journal* 21: 149–158.
- White, M. A. 2012. Long-term effects of deer browsing: composition, structure and productivity in a northeastern Minnesota old-growth forest. *Forest Ecology and Management* 269: 222–228. <https://doi.org/10.1016/j.foreco.2011.12.043>
- White, M., and G. E. Host. 2003. Historic disturbance regimes and natural variability of Grand Portage National Monument Forest Ecosystems. Report to Grand Portage National Monument, Grand Portage, Minnesota, USA.
- Wilhelm, G. S., and L. A. Masters. 1995. Floristic Quality Assessment in the Chicago Region and Application Computer Programs. Revised. The Morton Arboretum, Lisle, Illinois, USA.
- Wolff, J. O. 1978. Food habits of snowshoe hares in interior Alaska. *Journal of Wildlife Management* 42: 148–153. <https://doi.org/10.2307/3800702>
- York, R. A., J. J. Battles, R. C. Wenk, and D. Saah. 2012. A gap-based approach for regenerating pine species and reducing surface fuels in multi-aged mixed conifer stands in the Sierra Nevada, California. *Forestry* 85: 203–213. <https://doi.org/10.1093/forestry/cpr058>

Received 27 October 2015

Accepted 24 May 2017

Note

The First Record for Altai Fescue, *Festuca altaica* (Poaceae), in Nova Scotia, from an Eastern Alpine Site on Cape Breton Island

STEPHEN DARBYSHIRE¹, SEAN BLANEY^{2, 4}, and SEAN BASQUILL³

¹Agriculture and Agri-Food Canada, Ottawa Research and Development Centre, Building 49, 960 Carling Avenue, Ottawa, Ontario K1A 0C6 Canada

²Atlantic Canada Conservation Data Centre, P.O. Box 6416, Sackville, New Brunswick E4L 1G6 Canada

³Nova Scotia Department of Natural Resources, Wildlife Division, 136 Exhibition Street, Kentville, Nova Scotia B4N 4E5 Canada

⁴Corresponding author: sblaney@mta.ca

Darbyshire, Stephen, Sean Blaney, and Sean Basquill. 2017. The first record for Altai Fescue, *Festuca altaica* (Poaceae), in Nova Scotia, from an eastern alpine site on Cape Breton Island. *Canadian Field-Naturalist* 131(2): 164–169. <https://doi.org/10.22621/cfn.v131i2.1861>

Altai Fescue, *Festuca altaica* Trinius, is an amphi-Beringian grass species also known from isolated, but widespread, locations in northeastern North America. The occurrence reported here, at the southern limit of eastern alpine habitat in Canada, represents the first for Nova Scotia.

Key Words: Altai Fescue; *Festuca altaica*; conservation; rare plants; floristics; alpine vegetation; Nova Scotia

The distribution of *Festuca altaica* Trinius ranges from the Altai Mountains of central Asia (Tsvelev 1983) eastward and northward across the Bering Sea to northwestern North America and, from there, southward in British Columbia and western Alberta in alpine tundra (Pavlick and Looman 1984; Alexeev 1985; Harms 1985; Darbyshire and Pavlick 2007; Saarela *et al.* 2017). It also occurs in scattered areas in boreal forest and alpine regions of eastern North America, including northern Michigan, Quebec, Labrador, and western Newfoundland (Darbyshire and Pavlick 2007; Figure 1).

Here we document its first known occurrence in Nova Scotia, where a small but well established population was discovered during a qualitative botanical survey north of Polletts Cove, Cape Breton Island (Figure 2), in 2013. Although only a single localized population was found near the edge and crest of the plateau, more sites may well be found in this poorly explored region of fragmented barrens. This site is approximately 150 km and 340 km from the species' nearest locations in western Newfoundland and southeastern Quebec, respectively, which are isolated by ocean water (Figure 1). The plant occurred in small, scattered patches (none larger than a few square metres) over an area of about 50 × 10 m, within a tundra-like grassland, treeless (except for a few scattered krumholtz White Spruce, *Picea glauca* (Moench) Voss) and containing scattered forbs and shrubs. This habitat is classified as eastern alpine vegetation, which is one of the habitats in eastern Canada most vulnerable to environmental and climatic changes (Jones and Wiley 2012; Capers *et al.* 2013).

The scattered meta-populations of *F. altaica* in eastern Canada have sometimes been referred to other taxa

in the taxonomically controversial Rough Fescue complex (section *Breviaristatae*), including Plains Rough Fescue (*F. hallii* (Vasey) Piper; Alexeev 1985) and Mountain Rough Fescue (*F. altaica* subsp. *scabrella* (Torrey) Hultén (= *F. campestris* Rydberg); Harms 1985). As indicated by Pavlick and Looman (1984), populations in eastern North America appear to be most closely linked with *F. altaica* (in the narrow taxonomic sense) through morphological, phytogeographical, and ecological aspects (Darbyshire and Pavlick 2007).

Festuca altaica occupies a wide range of substrates and habitats throughout its range, including sandy plains, rocky slopes, cliffs, and talus in open boreal, subarctic, and subalpine forests, as well as low arctic and alpine tundra. It is often present in serpentine barrens in British Columbia, Quebec, and Newfoundland, but is also present on limestone and Precambrian bedrock (herbarium label data). The northern plateau of Cape Breton Island, where the population occurs at 412–427 m above sea level, is composed of Precambrian igneous and metamorphic rock (Roland 1982; Barr *et al.* 1992). Soil at the site consists of a 6-cm layer of humus over a fine, loamy-textured mineral soil about 20 cm deep.

In 2013, close associates of *F. altaica* and community structure were analyzed in two 25-m² plots within the area where this species is the dominant component. Plot SB1066 was at the crest of the slope on the plateau and SB1216 was on the upper slope (Figure 2, Table 1). The fieldwork was the first botanical exploration of the Polletts Cove plateau, and it documented numerous other provincially rare species with northern affinities both on the plateau and in the adjacent Blair River Valley (Table 2). Taxonomy and nomenclature in the tables follow Brouillet *et al.* (2010+), Esslinger (2015), and Ireland

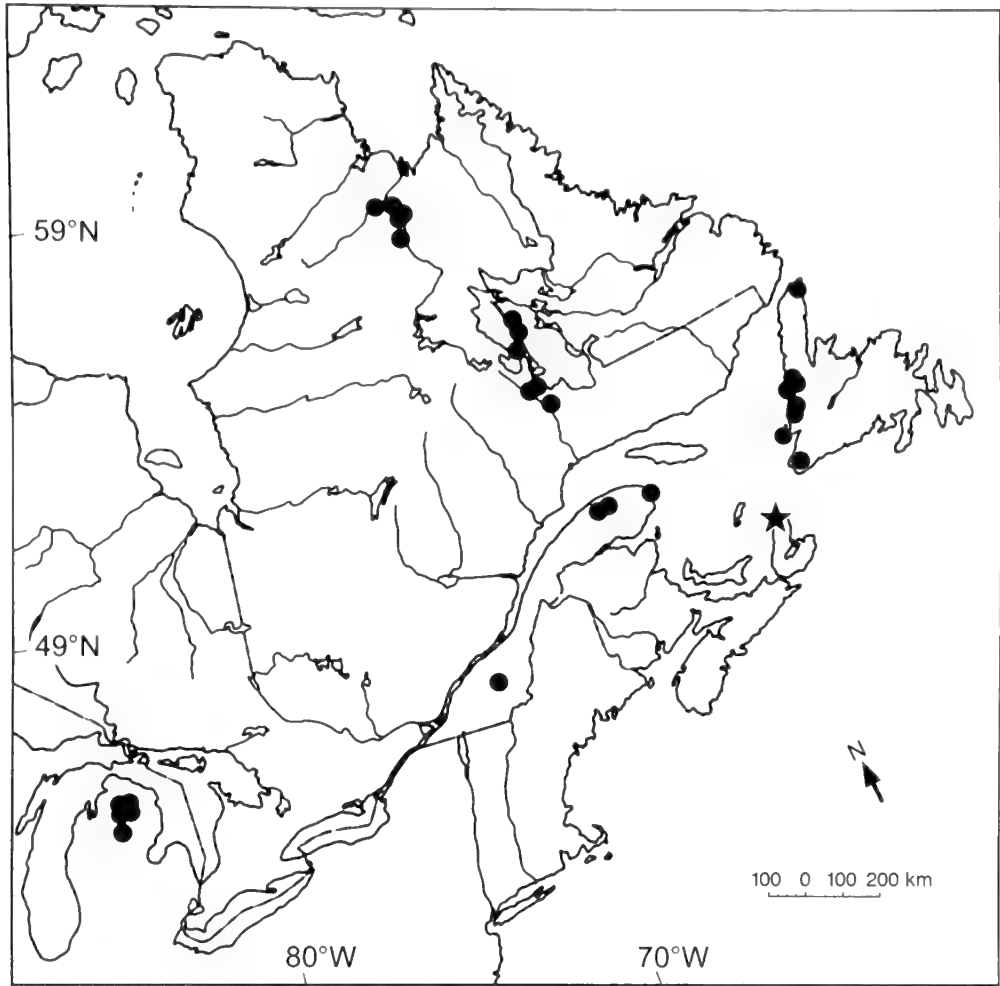


FIGURE 1. Distribution of Altai Fescue (*Festuca altaica*) in eastern North America, including the collection reported here from Nova Scotia (star). Sources: Aiken and Darbyshire (1990) and Atlantic Canada Conservation Data Centre, Sackville, New Brunswick, Canada.

(1982); common names of vascular plants are from Brouillet *et al.* (2010+). Provincial status ranks (S-ranks) in Table 2 were developed using the methods of NatureServe (2017).

The widespread and isolated occurrences of *F. altaica* in eastern North America suggest that current metapopulations are relicts of a more continuous distribution when tundra vegetation followed the glacial margin retreat northward and was subsequently modified by long-term (Hypsithermal) and short-term Holocene climate variation (Roland and Smith 1969; Webb *et al.* 1983; Ritchie 1987; Viau *et al.* 2006; Capers *et al.* 2013). Species of plants (and animals) responded to these changes in complex ways, both as communities and individually (Overpeck *et al.* 1992; Henry and Molau 1997; Jump and Peñuelas 2005; Walther 2010). A somewhat similar distribution is seen for Timber Oatgrass (*Danthonia intermedia* Vasey; Cayouette and Darbyshire 1987; Darbyshire 2003). Although this

latter species has not been found in Nova Scotia, both are relatively large-seeded grasses with boreal, arctic, or alpine affinities and no obvious means of long distance seed dispersal.

A combination of character states easily distinguished *F. altaica* from other species of *Festuca* in Nova Scotia in either vegetative or reproductive states. Measurements and observations of the limited material of *F. altaica* available from the Nova Scotia population showed character states well within the range reported for the species as a whole as listed below (Darbyshire and Pavlick 2007). It is a densely tufted grass with plentiful sterile shoots arising from within the persistent old leaf sheaths (intravaginal shoots) and, unlike Red Fescue (*F. rubra* L.) and Proliferous Fescue (*F. prolifera* (Piper) Fernald), creeping rhizomes are absent, although short extravaginal shoots may sometimes be present. Other species of *Festuca* present in Nova Scotia are Hair Fescue (*F. filiformis* Pourret), Nodding Fescue

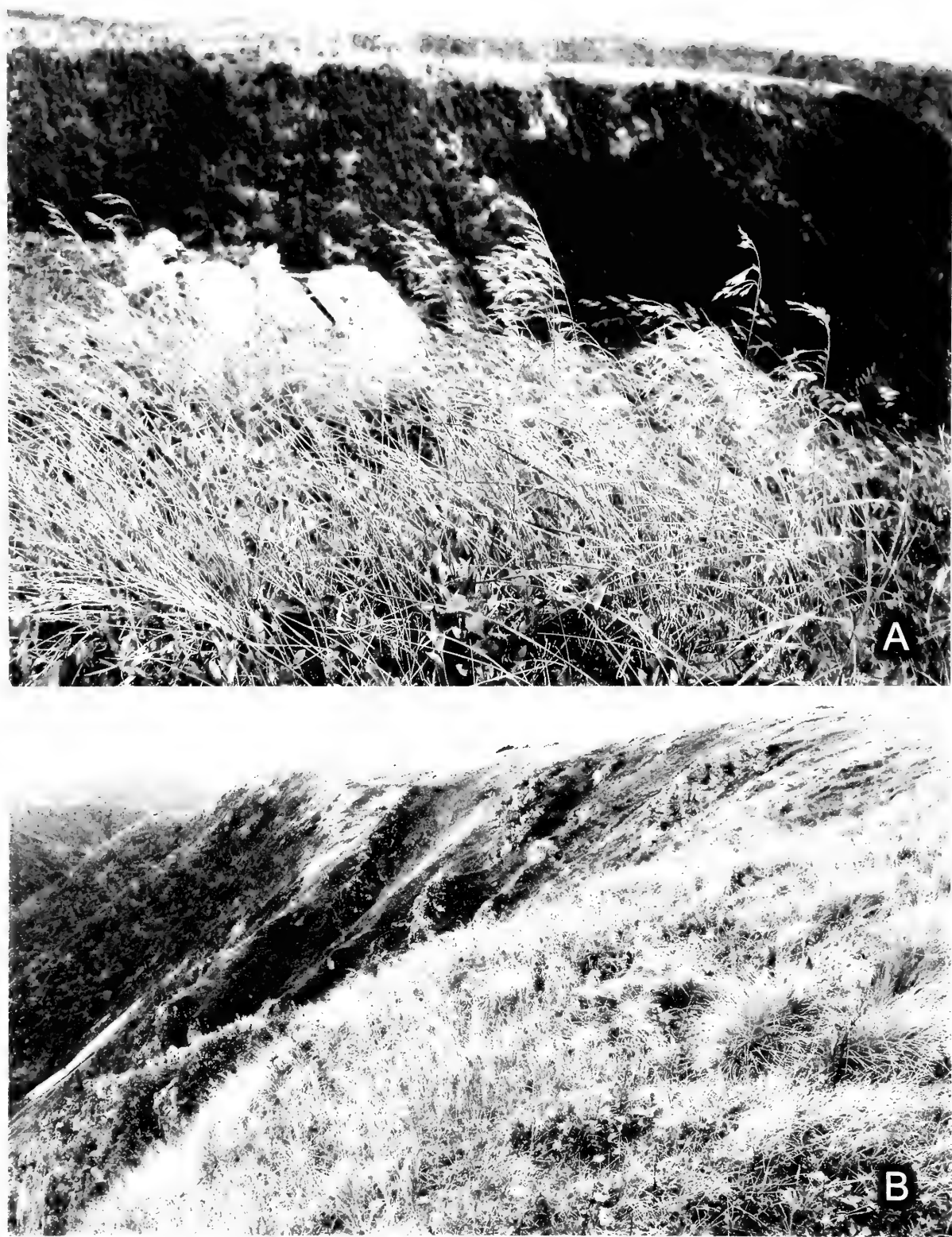


FIGURE 2. Alpine vegetation on Polletts Cove plateau, Nova Scotia, with Altai Fescue (*Festuca altaica*) in foreground. A. 15 July 2016. Photo: S. Blaney. B. 4 October 2013. Photo: S. Basquill.

TABLE 1. Percentage cover of vegetation in two plots (25 m²) containing Altai Fescue (*Festuca altaica*) at Polletts Cove plateau, Nova Scotia. The total number of species (and unique species) at plot SB1066 at the crest of the slope and plot SB1216 on the upper slope were 22 (7) and 32 (17), respectively.

Species		Cover, %	
		Plot SB1066	Plot SB1216
WOODY PLANTS			
Green Alder	<i>Alnus alnobetula</i> subsp. <i>crispa</i> (Aiton) Raus	1.50	3.00
Black Chokeberry	<i>Aronia melanocarpa</i> (Michaux) Elliot	0.10	0.03
Beaked Hazel	<i>Corylus cornuta</i> Marshall	*	0.10
Northern Bush-honeysuckle	<i>Diervilla lonicera</i> Miller		0.10
Mountain Holly	<i>Ilex mucronata</i> (L.) M. Powell, Savolainen & S. Andrews	0.50	
White Spruce	<i>Picea glauca</i> (Moench) Voss (single tree < 0.5 m tall)	0.50	
Virginia Rose	<i>Rosa virginiana</i> Miller	0.05	0.20
Broad-leaved Meadowsweet	<i>Spiraea alba</i> var. <i>latifolia</i> (Aiton) Dippel	1.00	0.10
Lowbush Blueberry	<i>Vaccinium angustifolium</i> Aiton	15.00	
Northern Blueberry	<i>Vaccinium boreale</i> L. V. Hall & Aalders	—	1.00
HERBACEOUS PLANTS			
Common Yarrow	<i>Achillea millefolium</i> L.	0.10	0.10
Rough Bentgrass	<i>Agrostis scabra</i> Willdenow		0.10
Alpine Bistort	<i>Bistorta vivipara</i> (L.) Delarbre	—	< 0.01
Canada Bluejoint	<i>Calamagrostis canadensis</i> (Michaux) Palisot de Beauvois	15.00	—
Sedge species	<i>Carex</i> sp.	0.02	—
Bluebead Lily	<i>Clintonia borealis</i> (Aiton) Rafinesque	0.10	0.30
Goldthread	<i>Coptis trifolia</i> (L.) Salisbury	—	0.10
Bunchberry	<i>Cornus canadensis</i> L.	0.01	
Wavy Hairgrass	<i>Deschampsia flexuosa</i> (L.) Trinius	5.00	1.00
Flat-topped White Aster	<i>Doellingeria umbellata</i> (Miller) Nees von Esenbeck	0.50	4.00
Stiff Eyebright	<i>Euphrasia stricta</i> J. F. Lehmann	—	0.10
Altai Fescue	<i>Festuca altaica</i> Trinius	30.00	60.00
Wild Strawberry	<i>Fragaria virginiana</i> Duchesne	—	0.02
Hairy Woodrush	<i>Luzula acuminata</i> Rafinesque	—	0.10
Three-leaved Rattlesnakeroot	<i>Nabalus trifoliolatus</i> Cassini	1.00	0.01
Whorled Wood Aster	<i>Oclemena acuminata</i> (Michaux) Greene	0.50	—
Three-tooth Cinquefoil	<i>Sibbaldia tridentata</i> (Aiton) Paule & Soják	0.03	1.00
Downy Goldenrod	<i>Solidago puberula</i> Nuttall	2.00	0.03
Mountain Cranberry	<i>Vaccinium vitis-idaea</i> L.	0.10	0.10
BRYOPHYTES AND LICHENS			
Stubby Stalked Lichen	<i>Cladonia caespiticia</i> (Persoon) Flörke	—	0.01
Forking Lichen	<i>Cladonia furcata</i> (Hudson) Schrader	—	0.01
Pebbled Pixie-cup Lichen	<i>Cladonia pyxidata</i> (L.) Hoffmann	—	0.01
Wavy-leaved Broom Moss	<i>Dicranum polysetum</i> Swartz	—	0.01
Stairstep Moss	<i>Hylocomium splendens</i> (Hedwig) Schimper		1.00
Pellucid Plait Moss	<i>Hypnum imponens</i> Hedwig		0.10
Red-stemmed Feather Moss	<i>Pleurozium schreberi</i> (von Bridel) Mitten	0.01	1.00
Yellow-green Rock Moss	<i>Racomitrium heterostichum</i> (Hedwig) von Bridel		0.01
Wooly Rock Moss	<i>Racomitrium lanuginosum</i> (Hedwig) von Bridel	—	0.01

*Indicates absence or undetected.

(*F. subverticillata* (Persoon) E. B. Alexeev), and Hard Fescue (*F. trachyphylla* (Hackel) Krajina) — lack rhizomes entirely.

Leaf blade characters are useful for identifying *Festuca* species (Darbyshire and Pavlick 2007). The leaf blades of the sterile shoots of *F. altaica* are conduplicate or convolute (rarely flat), 2–4 mm wide, up to about 50 cm long, strongly scabrous on the abaxial surface, and short pubescent (sometimes sparsely) on the adaxial surface. In cross section, “girders” of sclerenchyma tissue are present at the major veins, extending from the abaxial to adaxial epidermis, while, at the minor veins, “pillars” of sclerenchyma tissue extend from the abaxial

epidermis to the vein. In Nova Scotia, only *F. subverticillata* has sclerenchyma girders, but this species has flexuous leaf blades (3–5–10 mm wide (see illustrations in Darbyshire and Pavlick 2007) and grows in lowland deciduous or mixed forests.

Lemmas of *F. altaica* are (6.5) 7.5–9.0 (12.0) mm long with a terminal awn to about 1.5 mm long, whereas the lemmas of *F. filiformis* and *F. subverticillata* are shorter (≤ 4.5 mm long) and lack awns. The lemmas of *F. trachyphylla* are 3.8–6.5 mm long and awned. Anthers of *F. altaica* are 2.6–4.5 (5) mm long, whereas the anthers of *F. filiformis* and *F. subverticillata* are ≤ 2.2 mm long and those of *F. trachyphylla* and *F. rubra* are

TABLE 2. Additional significant species at the Polletts Cove site and the Blair River ravine, Nova Scotia.

Species		Affinity	Status in Nova Scotia, [†] no. known sites [‡]
Cream-flowered Rockcress	<i>Arabis pycnocarpa</i> M. Hopkins	Widespread	S1S2, 7
Field Wormwood	<i>Artemisia campestris</i> L.	Boreal	S1, 2
Bog Birch	<i>Betula pumila</i> L. var. <i>pumila</i> *	Boreal	S2, 11
Alpine Bistort	<i>Bistorta vivipara</i> (L.) Delarbre*	Arctic/alpine	S1, 2
Hair-like Sedge	<i>Carex capillaris</i> L.	Boreal, arctic/alpine	S2, 13
Single-spike Sedge	<i>Carex scirpoidea</i> Michaux subsp. <i>scirpoidea</i>	Arctic/alpine	S2, 13
Laurentian Bladder Fern	<i>Cystopteris laurentiana</i> (Weatherby) Blasdel	Eastern	S2, 10
Rock Draba	<i>Draba arabisans</i> Michaux	Eastern	S2, 16
Meadow Barley	<i>Hordeum brachyantherum</i> Nevski	Western (also northwestern Newfoundland and southern Labrador)	S1, 2
Spiked Woodrush	<i>Luzula spicata</i> (L.) de Candolle*	Boreal	S1, 4
Highland Rush	<i>Oreojuncus trifidus</i> (L.) Závorská, Drábková & Kirschner*	Eastern	S2S3, 18
Saint John River Locoweed	<i>Oxytropis campestris</i> var. <i>johannensis</i> Fernald	Eastern	S1S2, 5
Glaucous Bluegrass	<i>Poa glauca</i> Vahl*	Boreal	S2S3, 20
Nodding Saxifrage	<i>Saxifraga cernua</i> L.	Arctic/alpine	S1, 1
Purple Mountain Saxifrage	<i>Saxifraga oppositifolia</i> L.	Arctic/alpine	S1, 2
Laestadius' Saxifrage	<i>Saxifraga paniculata</i> subsp. <i>laestadii</i> (Neuman) T. Karlsson	Boreal, arctic/alpine	S2, 16
Multi-rayed Goldenrod	<i>Solidago multiradiata</i> Aiton	Boreal	S2, 10
Quill Lichen	<i>Cladonia amaurocraea</i> (Flörke) Schaerer*	Boreal, arctic/alpine	S1, 1

*Species found in close proximity to Altai Fescue (*Festuca altaica*) on the plateau crest and upper slopes; others were found on cliff or riparian habitats in the adjacent ravine. All species except Nodding Saxifrage (*Saxifraga cernua*) were found during the same 2013 survey that detected *F. altaica*.

[†]Source: Atlantic Canada Conservation Data Centre, Sackville, New Brunswick, Canada. Accessed 1 June 2017.

[‡]Includes the ones reported here.

mostly 2–3.5 mm long, although the anthers of Rock Red Fescue (*F. rubra* subsp. *pruinosa* (Hackel) Piper) may be up to 6.5 mm long. The apex of the ovaries in *F. altaica* is usually sparsely pubescent, but densely pubescent in *F. subverticillata* and glabrous in other *Festuca* species present in Nova Scotia.

Voucher specimens

Canada, Nova Scotia, Inverness Co., 46.927°N, 60.669°W, alpine summit, plateau barren, 18 July 2013, C.S. Blaney, D.M. Mazerolle, and S.P. Basquill 8330. (ACAD, DAO, NBM, NSPM).

Acknowledgements

We thank Eugene Quigley and David Mazerolle for assistance with fieldwork.

Literature Cited

Aiken, S. G., and S. J. Darbyshire. 1990. Fescue Grasses (*Festuca* L.: Poaceae) of Canada. Publication 1844/E. Agriculture and Agri-Food Canada, Ottawa, Ontario, Canada.

Alexeev, E. B. 1985. *Festuca* L. (Poaceae) in Alaska et Canada. Novosti Sistematiki Vysshikh Rastenii 22: 5–35. [In Russian].

Barr, S. M., R. A. Jamieson, and R. P. Raeside. 1992. Geological map of Northern Cape Breton Island. DP ME 13, Version 2, 2006. Digital version of Geological Survey of Canada map 1752A. Geological Survey of Canada, Ottawa,

Ontario, Canada. Accessed 7 June 2017. <https://novascotia.ca/natr/meb/download/dp013.asp>.

Brouillet, L., F. Coursol, S. J. Meades, M. Favreau, M. Anions, P. Bélisle, and P. Desmet. 2010+. VASCAN, the database of vascular plants of Canada. Université de Montréal Biodiversity Centre, Montréal, Quebec, Canada. Accessed 22 September 2016. <http://data.canadensys.net/vscan>.

Capers, R. S., K. D. Kimball, K. P. McFarland, M. T. Jones, A. H. Lloyd, J. S. Munroe, G. Fortin, C. Mat-trick, J. Goren, D. D. Sperduto, and R. Paradis. 2013. Establishing alpine research priorities in northeastern North America. Northeastern Naturalist 20: 559–577. <https://doi.org/10.1656/045.020.0406>

Cayouette, J., and S. J. Darbyshire. 1987 [1988]. La répara-tition de *Danthonia intermedia* dans l’est du Canada. Le Naturaliste canadien 114: 217–220.

Darbyshire, S. J. 2003. *Danthonia* DC. Pages 301–306 in Flora of North America North of Mexico, Volume 25: Mag-noliophyta: Commelinidae (in Part): Poaceae, Part 2. *Edited* by Flora of North America Editorial Committee. Oxford University Press, New York, New York, USA.

Darbyshire, S. J., and L. E. Pavlick. 2007. *Festuca* L. Pages 389–443 in Flora of North America North of Mexico, Vol-ume 24: Magnoliophyta: Commelinidae (in Part): Poaceae, Part 1. *Edited* by Flora of North America Editorial Com-mittee. Oxford University Press, New York, New York, USA.

Esslinger, T. L. 2015. A cumulative checklist for the lichen-forming, lichenicolous and allied fungi of the continental

- United States and Canada. Version 20. North Dakota State University, Fargo, North Dakota, USA. Accessed 22 September 2016. <http://www.ndsu.edu/pubweb/~esslinge/checklst/checklst7.htm>.
- Harms, V. L.** 1985. A reconsideration of the nomenclature and taxonomy of the *Festuca altaica* complex (Poaceae) in North America. *Madroño* 32: 1–10.
- Henry, G. H. R., and U. Molau.** 1997. Tundra plants and climate change: the International Tundra Experiment (ITEX). *Global Change Biology* 3 (Suppl. 1): 1–9. <https://doi.org/10.1111/j.1365-2486.1997.gcb132.x>
- Ireland, R. R.** 1982. Moss Flora of the Maritime Provinces. Publications in botany 13. National Museum of Natural Sciences, Ottawa, Ontario, Canada.
- Jones, M. T., and L. L. Willey.** 2012. Eastern Alpine Guide: Natural History and Conservation of Mountain Tundra East of the Rockies. Beyond Ktaadn, Inc. and Boghaunter Books, New Salem, Massachusetts, USA.
- Jump, A. S., and J. Peñuelas.** 2005. Running to stand still: adaptation and the response of plants to rapid climate change. *Ecology Letters* 8: 1010–1020. <https://doi.org/10.1111/j.1461-0248.2005.00796.x>
- NatureServe.** 2017. Conservation status assessment: identifying threatened species and ecosystems. NatureServe, Arlington, Virginia, USA. Accessed 9 June 2017. <http://www.natureserve.org/conservation-tools/conservation-status-assessment>.
- Overpeck, J. T., R. S. Webb, and T. Webb, III.** 1992. Mapping eastern North American vegetation change of the past 18 ka: no-analogs and the future. *Geology* 20: 1071–1074. [https://doi.org/10.1130/0091-7613\(1992\)020<1071:MENAVC>2.3.CO;2](https://doi.org/10.1130/0091-7613(1992)020<1071:MENAVC>2.3.CO;2)
- Pavlick, L. E., and J. Looman.** 1984. Taxonomy and nomenclature of rough fescues, *Festuca altaica*, *F. campestris* (*F. scabrella* var. *major*), and *F. hallii*, in Canada and the adjacent part of United States. *Canadian Journal of Botany* 62: 1739–1749. <https://doi.org/10.1139/b84-235>
- Ritchie, J. C.** 1987. Postglacial Vegetation of Canada. Cambridge University Press, Cambridge, United Kingdom. <https://doi.org/10.1002/jqs.3390050209>
- Roland, A. E.** 1982. Geological Background and Physiography of Nova Scotia. Nova Scotia Institute of Science, Halifax, Nova Scotia, Canada.
- Roland, A. E., and E. C. Smith.** 1969. The flora of Nova Scotia. Part II. The dicotyledons. *Proceedings of the Nova Scotia Institute of Science* 26: 277–742.
- Saarela, J. M., P. C. Sokoloff, and R. D. Bull.** 2017. Vascular plant biodiversity of the lower Coppermine River valley and vicinity (Nunavut, Canada): an annotated checklist of an Arctic flora. *PeerJ* 5: e2835. <https://doi.org/10.7717/peerj.2835>
- Tsvelev, N. N.** 1983. Grasses of the Soviet Union. Oxonian Press, New Delhi, India.
- Viau, A. E., K. Gajewski, M. C. Sawada, and P. Fines.** 2006. Millennial-scale temperature variations in North America during the Holocene. *Journal of Geophysical Research* 111: D09102. <https://doi.org/10.1029/2005JD006031>
- Walther, G.-R.** 2010. Community and ecosystem responses to recent climate change. *Philosophical Transactions of the Royal Society B* 365: 2019–2024. <https://doi.org/10.1098/rstb.2010.0021>
- Webb, T., III, P. J. H. Richard, and R. J. Mott.** 1983. A mapped history of Holocene vegetation in southern Quebec. *Syllogeus* 49: 273–331.

Received 23 September 2016

Accepted 9 August 2017

Trends in Bird Densities at a Remnant Fescue Grassland in Saskatchewan

BOHDAN PYLYPEC

Department of Plant Sciences, University of Saskatchewan, Saskatoon, Saskatchewan S7N 5A8 Canada; email: bohdan.pylypec@usask.ca

Pylypec, Bohdan. 2017. Trends in bird densities at a remnant fescue grassland in Saskatchewan. *Canadian Field-Naturalist* 131(2): 170–178. <https://doi.org/10.22621/cfn.v131i2.1904>

Populations of grassland birds in North America have declined greatly in the past five decades. Hypothesized drivers of decline include habitat loss, fragmentation, and adverse impacts from human activities. At a remnant fescue grassland in Saskatoon, Saskatchewan numbers of Savannah Sparrow (*Passerculus sandwichensis*), Western Meadowlark (*Sturnella neglecta*), Brewer's Blackbird (*Euphagus cyanocephalus*), and Vesper Sparrow (*Pooecetes gramineus*) have been stable. Numbers of Clay-colored Sparrow (*Spizella pallida*) have increased since the 1960s. Sprague's Pipit (*Anthus spragueii*), Upland Sandpiper (*Bartramia longicauda*), and Burrowing Owl (*Athene cunicularia*) are no longer present. Baird's Sparrow (*Ammodramus bairdii*), Bobolink (*Dolichonyx oryzivorus*), and Horned Lark (*Eremophila alpestris*) have become irregular visitors. In the past 50 years, 91 species have been observed displaying territorial behaviour, feeding, nesting, or migrating at this remnant native grassland. With encroaching urban development and increased human influence at the prairie and surrounding area, the impacts on the bird communities at the site in the future are unknown.

Key Words: Bird population density trends; fescue grassland; grassland bird specialists; Saskatchewan

Introduction

In the Prairie Ecozone of southern Saskatchewan native grasslands comprise 21% of the land area (51 628 km²; Acton *et al.* 1998; Hammermeister *et al.* 2001). Most of these grasslands occur as small, fragmented patches except for a few larger contiguous patches in the extreme southwest portion of the province. In the Moist Mixed Grassland Ecoregion within this region, only 5.3% is native grassland usually in remnant patches (Gauthier and Wiken 2003), and in local areas of prime cropland less than 2% of the original prairie remains (Hammermeister *et al.* 2001).

One of the largest remnants of this type of grassland is the Kernen Prairie, a 130 ha Fescue Prairie now within the city limits of Saskatoon, Saskatchewan (52.167°N, 106.55°W, elevation 510 m). The prairie is in the Saskatoon Plain Landscape Area in the Moist Mixed Grassland Ecoregion of the Prairie Ecozone (Acton *et al.* 1998). Coupland and Brayshaw (1953) and Coupland (1961) described the Fescue Prairie in Saskatchewan, and native plant communities at Kernen Prairie have been described by Baines (1964, 1973), Pylypec (1986), and Gross and Romo (2010a,b). Plains Rough Fescue (*Festuca hallii* (Vasey) Piper) is the dominant graminoid species with Northern Porcupine Grass (*Hesperostipa curtipetala* (Hitchcock) Barkworth), Thick-spike Wildrye (*Elymus lanceolatus* (Scribner & J.G. Smith) Gould), and Slender Wildrye (*Elymus trachycaulus* (Link) Gould ex Shinnery) also important species. Important shrub communities are dominated by Western Snowberry (*Symphoricarpos occidentalis* Hooker), Wolf-willow (*Elaeagnus commutata* Bernhardt ex Ryd-

berg), Prairie Rose (*Rosa arkansana* Porter), Woods' Rose (*Rosa woodsii* Lindley), and White Meadowsweet (*Spiraea alba* Du Roi). Tree species are not prominent in the prairie; four bluffs and several small patches of Trembling Aspen (*Populus tremuloides* Michaux) are present as well as several Bebb's Willow (*Salix bebbiana* Sargent) stands in depressional sites. In total, 165 species of vascular plants representing 34 families have been recorded at Kernen Prairie (Pylypec 1986).

Kernen Prairie was part of the Kernen family homestead in 1917 and was used for grazing by cattle and horses until the 1930s (Baines 1964). Between that period and the 1970s it was disturbed only minimally; some areas were lightly grazed and mowed periodically. One small area (1300 m × 10 m) 700 m from the bird study plot was tilled in 1963. That tract of land was used as an airstrip until the mid-1970s, and was revegetated with the exotic grass Smooth Brome (*Bromus inermis* Lysse) and also with native prairie species. In 1977, Mr. Fred Kernen bequeathed the prairie to the University of Saskatchewan and since that time it is being managed as an ecological reserve. The site, however, has been affected by altered disturbance regimes, invasive species, and encroaching urbanization.

Fire, either started by lightning or indigenous peoples, was a historically essential process in the prairie landscape that maintained a mosaic of vegetation patches and biodiversity (Romo 2003). At the Kernen Prairie fire was suppressed for at least a century although prescribed burns of different sizes have been used various times beginning in 1986 (Gross and Romo 2010a).

Kernen Prairie is currently undergoing invasion by a number of non-native species mainly Smooth Brome with lesser amounts of Kentucky Bluegrass (*Poa pratensis* L.), Field Sow-thistle (*Sonchus arvensis* L.), and Canada Thistle (*Cirsium arvense* (L.) Scopoli). Vegetation surveys in 2006 (B.P., unpublished data) indicated approximately 15% of the prairie was occupied by these species. Smooth Brome is an introduced species that has naturalized in Canada, and combined with its competitive superiority over several native grasses has displaced native species in many grasslands in North America including the fescue grassland at Kernen Prairie (Grilz and Romo 1995; Otfinowski *et al.* 2007). To control the spread of this species, conservation grazing with cattle at light grazing loads (0.3–0.4 animal units/ha) was initiated in 2006 for the May to September grazing period (Mori 2009) and the grazing is on-going.

Kernen Prairie can be considered as an island of native vegetation in a matrix of cropland and urban development (Forman 1995). Aerial photographs of the area from 1944 show this remnant prairie was already surrounded by cropland. Gravel roads along the north and east sides were established in the 1960s. In 2010 urban housing development began 800 m west of the prairie, and in 2015 the area at the northern boundary of the prairie was developed for future urban expansion.

Grassland birds have declined sharply over the past five decades due to habitat loss and degradation (Owens and Myres 1973; Kantrud and Kologiski 1982; Davis 2004; Askins *et al.* 2007; Henderson and Davis 2014). These grassland bird declines are more severe than those documented for any other behavioural or ecological guild of North American birds (Knopf 1994; Sampson and Knopf 1994). Eight species recorded at Kernen Prairie have been assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; SARA Registry 2017). Burrowing Owl (*Athene cunicularia*) is listed in Schedule 1 of the *Species at Risk Act* (SARA) as endangered while Loggerhead Shrike (*Lanius ludovicianus*) and Sprague's Pipit (*Anthus spragueii*) are listed as threatened. Long-billed Curlew (*Numenius americanus*), Short-eared Owl (*Asio flammeus*), and Baird's Sparrow (*Ammodramus bairdii*) are listed as species of special concern (SARA Registry 2017). Bobolink (*Dolichonyx oryzivorus*) and Lark Bunting (*Calamospiza melanocorys*) have been assessed as threatened by COSEWIC but are not yet on Schedule 1 (SARA Registry 2017).

The objectives of this study are to (1) document changes in the densities of breeding populations of grassland bird specialists over the past 50 years at a remnant native fescue grassland, (2) relate these to habitat and landscape changes at the study site over the same period, and (3) compare with trends in southern Saskatchewan as indicated in the Breeding Bird Survey (BBS) for 1970–2012.

Methods

Breeding bird densities were studied at an 18.6 ha gridded plot with grid markers at 60 m intervals that was established in 1966. Bird populations were first studied by M. R. Lein and D. J. Karasiuk from 1966 to 1970 (Lein 1968; Karasiuk 1973). This study was from 1987 to 1989 (Pylypec 1991) and then from 2005 to 2016. All of these studies were conducted on the same plot and the same methods were used to determine breeding bird densities.

Breeding birds were censused using the mapping method described by Kendiegh (1944) and Davis (1965). Censuses of approximately 2.5 h duration were conducted approximately twice weekly during the breeding season from May to July in each of the years of this study. The censuses were conducted between 08:00 and 10:30 when weather conditions were favourable for seeing and hearing singing males. During each census, locations of birds exhibiting territorial behaviour such as singing at perches, aerial flight displays, and conflicts between neighbouring males were recorded on a map of the plot. These data points were used to map the breeding territories of each species and to determine their breeding density. For example, if 30 territories were noted on the plot, the density was determined to be 1.61 pairs/ha.

Brewer's Blackbirds (*Euphagus cyanocephalus*) nested in two loose colonies at the plot. As these birds do not exhibit well-defined individual breeding territories, their densities were estimated from the maximum number of males observed showing territorial behaviour at the colonies. Observations of migrating birds and birds in the immediate vicinity of the plot were also noted.

Bird population data and habitat descriptions prior to this study were obtained from earlier studies at the site (Lein 1968; Karasiuk 1973; Pylypec 1991). Also, historical aerial photographs of the prairie were examined. Status and abundance for all species observed at the prairie were determined using definitions given by Roy (1996), Smith (1996), Leighton *et al.* (2002), and Saskatoon Nature Society (2010; Table 1). Annual trend, indicated as average annual percent change in the population, was noted for each species using BBS data for the pothole region of southern Saskatchewan (BCR11) for the 1970–2012 period (Environment Canada 2014).

Results and Discussion

A total of 91 species were observed displaying territorial behaviour, feeding, nesting, or migrating at Kernen Prairie from 1966 to 2016. Twenty-one species were recorded with definite breeding records, 52 species as summer residents in the Saskatoon area but with no definite breeding records at the Kernen Prairie, five species as permanent residents in the Saskatoon area but with no definite breeding records at the prairie, and 13 spring transients (Table 1).

TABLE 1. List of species observed at Kernen Prairie, their occurrence* and abundance† at Kernen Prairie and in the Saskatoon area, and Breeding Bird Survey (BSS) trends‡ in southern Saskatchewan.

Occurrence	Abundance			BBS trend in southern SK 1970–2012
	Kernen Prairie 1966–1970	Kernen Prairie 1987–1989	Saskatoon area 2002	
A. Summer and permanent residents with definite breeding records (<i>n</i> = 21)				
Gadwall (<i>Anas strepera</i>)	common	fairly common	fairly common	4.140
Mallard (<i>Anas platyrhynchos</i>)	common	common	common	–1.230
Blue-winged Teal (<i>Anas discors</i>)	common	fairly common	fairly common	1.640
Northern Pintail (<i>Anas acuta</i>)	common	fairly common	fairly common	–4.500
Sharp-tailed Grouse (<i>Tympanuchus phasianellus</i>)	common	fairly common	fairly common	–1.240
Northern Harrier (<i>Circus cyaneus</i>)	common	fairly common	fairly common	–1.740
Swainson's Hawk (<i>Buteo swainsoni</i>)	common	fairly common	fairly common	0.745
Upland Sandpiper (<i>Bartramia longicauda</i>)	fairly common	fairly common	absent	4.180
Great Horned Owl (<i>Bubo virginianus</i>)	fairly common	fairly common	absent	0.455
Burrowing Owl (<i>Athene cunicularia</i>)	common	absent	absent	ID
Eastern Kingbird (<i>Tyrannus tyrannus</i>)	common	common	fairly common	0.119
Black-billed Magpie (<i>Pica hudsonia</i>)	common	common	common	–0.902
Sprague's Pipit (<i>Anthus spragueii</i>)	abundant	common	irregular	–3.830
Clay-colored Sparrow (<i>Spizella pallida</i>)	abundant	abundant	abundant	–0.366
Vesper Sparrow (<i>Poocetes gramineus</i>)	common	common	common	0.595
Savannah Sparrow (<i>Passerculus sandwichensis</i>)	abundant	abundant	abundant	1.040
Baird's Sparrow (<i>Ammodramus bairdii</i>)	common	common	rare	–1.850
Bobolink (<i>Dolichonyx oryzivorus</i>)	uncommon	absent	irregular	0.703
Western Meadowlark (<i>Sturnella neglecta</i>)	common	common	common	–2.620
Brewer's Blackbird (<i>Euphagus cyanocephalus</i>)	common	common	common	–1.970
Brown-headed Cowbird (<i>Molothrus ater</i>)	common	uncommon	uncommon	1.190
B. Permanent residents but no breeding records (<i>n</i> = 5)				
Gray Partridge (<i>Pertlix perdix</i>)	fairly common	uncommon	uncommon	–0.057
Rock Pigeon (<i>Columba livia</i>)		uncommon	uncommon	–1.230
Downy Woodpecker (<i>Dryobates pubescens</i>)		absent	irregular	–0.804
Hairy Woodpecker (<i>Picoides villosus</i>)		absent	irregular	3.820
Pileated Woodpecker (<i>Dryocopus pileatus</i>)		absent	irregular	ND
C. Summer residents but no definite breeding records (<i>n</i> = 52)				
Canada Goose (<i>Branta canadensis</i>)		fairly common	common	9.030
American Wigeon (<i>Anas americana</i>)		absent	common	–3.670
Northern Shoveler (<i>Anas clypeata</i>)		irregular	common	2.330
Green-winged Teal (<i>Anas crecca</i>)		absent	uncommon	1.150
Double-crested Cormorant (<i>Phalacrocorax auritus</i>)		irregular	uncommon	4.680
Great Blue Heron (<i>Ardea herodias</i>)		absent	uncommon	–3.190

TABLE 1. (continued) List of species observed at Kernen Prairie, their occurrence* and abundance† at Kernen Prairie and in the Saskatoon area, and Breeding Bird Survey (BBS) trends‡ in southern Saskatchewan.

Occurrence	Abundance				BBS trend in southern SK 1970-2012
	Kernen Prairie		Saskatoon area		
	1966-1970	1987-1989	2005-2016	2002	
Turkey Vulture (<i>Cathartes aura</i>)		absent	irregular	rare	ND
Red-tailed Hawk (<i>Buteo jamaicensis</i>)		irregular	irregular	common	2,500
American Kestrel (<i>Falco sparverius</i>)		irregular	irregular	uncommon	-2,190
Merlin (<i>Falco columbarius</i>)		irregular	irregular	fairly common	4,820
Sora (<i>Porzana carolina</i>)		absent	irregular	common	2,110
American Coot (<i>Fulica americana</i>)		absent	irregular	common	2,790
Killdeer (<i>Charadrius vociferus</i>)		uncommon	uncommon	fairly common	-0,860
American Avocet (<i>Recurvirostra americana</i>)		absent	irregular	common	-0,808
Willet (<i>Tringa semipalmata</i>)		uncommon	uncommon	fairly common	-0,502
Lesser Yellowlegs (<i>Tringa flavipes</i>)		irregular	irregular	common	2,110
Long-billed Curlew (<i>Numenius americanus</i>)		absent	irregular	uncommon	0,178
Marbled Godwit (<i>Limosa fedoa</i>)		uncommon	uncommon	fairly common	-1,640
Wilson's Snipe (<i>Gallinago delicata</i>)		irregular	irregular	fairly common	3,710
Franklin's Gull (<i>Larus pipixcan</i>)		uncommon	uncommon	common	0,329
Ring-billed Gull (<i>Larus delawarensis</i>)		uncommon	uncommon	common	1,220
Black Tern (<i>Chlidonias niger</i>)		irregular	irregular	common	0,436
Mourning Dove (<i>Zenaidura macroura</i>)		irregular	irregular	fairly common	1,850
Northern Flicker (<i>Colaptes auratus</i>)		irregular	irregular	fairly common	2,750
Western Wood Pewee (<i>Contopus vordilii</i>)		absent	irregular	irregular	2,770
Least Flycatcher (<i>Empidonax minimus</i>)		irregular	irregular	common	2,580
Say's Phoebe (<i>Sayornis saya</i>)		absent	irregular	uncommon	2,960
Western Kingbird (<i>Tyrannus verticalis</i>)		irregular	irregular	common	1,800
Loggerhead Shrike (<i>Lanius ludovicianus</i>)		absent	irregular	uncommon	3,050
Red-eyed Vireo (<i>Vireo olivaceus</i>)		absent	irregular	common	-0,943
American Crow (<i>Corvus brachyrhynchos</i>)		fairly common	fairly common	common	3,120
Common Raven (<i>Corvus corax</i>)		absent	uncommon	uncommon	26,900
Horned Lark (<i>Eremophila alpestris</i>)	fairly common	fairly common	uncommon	fairly common	4,390
Tree Swallow (<i>Iachycineta bicolor</i>)		uncommon	uncommon	common	0,035
Barn Swallow (<i>Hirundo rustica</i>)	fairly common	uncommon	uncommon	common	0,990
House Wren (<i>Troglodytes aedon</i>)		irregular	irregular	common	0,355
Sedge Wren (<i>Cistothorus platensis</i>)		absent	irregular	uncommon	3,570
American Robin (<i>Turdus migratorius</i>)		absent	irregular	common	3,330
Gray Catbird (<i>Dumetella carolinensis</i>)		absent	irregular	fairly common	0,071
Brown Thrasher (<i>Toxostoma rufum</i>)		irregular	irregular	fairly common	0,451
European Starling (<i>Sturnus vulgaris</i>)		irregular	absent	uncommon	3,030
Cedar Waxwing (<i>Bombycilla cedrorum</i>)		irregular	irregular	common	0,589
Yellow Warbler (<i>Setophaga petea hui</i>)		absent	irregular	common	2,440
Ovenbird (<i>Seiurus aurocapilla</i>)		absent	irregular	uncommon	2,010

TABLE 1. (continued) List of species observed at Kernan Prairie, their occurrence* and abundance† at Kernan Prairie and in the Saskatoon area, and Breeding Bird Survey (BBS) trends‡ in southern Saskatchewan.

Occurrence	Abundance			BBS trend in southern SK 1970–2012
	1966–1970	Kernan Prairie 1987–1989	Saskatoon area 2002	
Chipping Sparrow (<i>Spizella passerina</i>)		absent	common	1.810
Lark Bunting (<i>Calamospiza melanocorys</i>)		irregular	rare	–5.760
Grasshopper Sparrow (<i>Ammodramus savannarum</i>)	irregular	absent	irregular	–2.360
LeConte’s Sparrow (<i>Ammodramus leconteii</i>)		absent	fairly common	0.996
Song Sparrow (<i>Melospiza melodia</i>)		absent	fairly common	–1.080
Red-winged Blackbird (<i>Agelaius phoeniceus</i>)	common	uncommon	abundant	–0.286
Yellow-headed Blackbird (<i>Xanthocephalus xanthocephalus</i>)		irregular	common	1.630
American Goldfinch (<i>Spinus tristis</i>)	uncommon	uncommon	common	0.016
D. Spring transients (<i>n</i> = 13)				
Greater White-fronted Goose (<i>Anser albifrons</i>)		irregular	abundant	ID
Snow Goose (<i>Chen caerulescens</i>)		absent	abundant	ID
Tundra Swan (<i>Cygnus columbianus</i>)		absent	abundant	ID
Bald Eagle (<i>Haliaeetus leucocephalus</i>)		absent	fairly common	ND
Cooper’s Hawk (<i>Accipiter cooperii</i>)		absent	uncommon	–1.200
Rough-legged Hawk (<i>Buteo lagopus</i>)		irregular	uncommon	ID
Sandhill Crane (<i>Grus canadensis</i>)		irregular	common	3.660
American Golden-plover (<i>Pluvialis dominica</i>)		irregular	fairly common	ID
Sanderling (<i>Calidris alba</i>)		absent	fairly common	ID
Snowy Owl (<i>Nyctea scandiaca</i>)		absent	fairly common	ID
Short-eared Owl (<i>Asio flammeus</i>)	irregular	irregular	irregular	–5.400
White-throated Sparrow (<i>Zonotrichia albicollis</i>)		absent	common	1.330
White-crowned Sparrow (<i>Zonotrichia leucophrys</i>)		irregular	fairly common	–2.500

*Occurrence of species in the Saskatoon area (Leighton *et al.* 2002):
Summer resident – species normally arrives in spring and departs in the fall;
Permanent resident – species remains throughout the year;
Spring resident – species passes through area in March to June en-route to northern breeding grounds;
Definite breeding record at Kernan Prairie – nest containing eggs or young, or newly fledged young observed.
†Abundance – indication of likelihood of a sighting assuming an experienced observer is in the preferred habitat of the species (Roy 1996; Smith 1996):
Abundant – can be found without any particular search, often in large numbers;
Common – can be found in substantial numbers with a minimum of searching;
Fairly common – can generally be found but usually in small numbers and with some searching;
Uncommon – may not be found on every trip and usually in small numbers or alone;
Rare – difficult to find because of extremely limited numbers;
Irregular – not present every year.
‡Percent annual change (1970–2012) indicated in BBS data (Environment Canada 2014); ID = insufficient data; ND = no data.

Nine of 21 species with breeding records on the plot (Figure 1) established breeding territories and were recorded regularly in censuses throughout the duration of this study (Lein 1968; Karasiuk 1973; Pylypec 1991). The most common was the Savannah Sparrow (*Passerculus sandwichensis*; Figure 1a). Breeding density averaged 1.50 pairs/ha (or 28 territories on the plot) and numbers have declined somewhat over the past 50 years (R Development Core Team 2016; Spearman rank correlation coefficient, $r_s = 0.641$, $P = 0.007$). Numbers were 1.61 pairs/ha in 1967 (Lein 1968), 1.70 pairs/ha in 1987–1989 (Pylypec 1991) and ranged from 1.18 pairs/ha to 1.75 pairs/ha in 2005–2016. In the pothole region of southern Saskatchewan BBS data for the 1970–2012 period indicates an average annual increase of 1.04% (Environment Canada 2014). This species utilizes shrubs for nesting cover and song perches but also feeds in open grassland vegetation (Lein 1968; Karasiuk 1973); these vegetation types were present throughout the duration of this study.

Clay-colored Sparrows (*Spizella pallida*) averaged 1.40 pairs/ha (26 territories on the plot) (Figure 1b). Densities were lowest (0.38 pairs/ha) in 1968 and 1969 (Karasiuk 1973) and numbers have increased ($r_s = 0.874$, $P < 0.001$) to a high of 2.02 pairs/ha in 2015.

In contrast, BBS data indicate an average annual decline of 0.366% for the same period in southern Saskatchewan (Environment Canada 2014). The preferred habitat of this species is dense brush patches (Knapton 1978; Kantrud and Kologiski 1982; Arnold and Higgins 1986; Madden *et al.* 2000). Judging from historical aerial photographs of the Kernen Prairie this vegetation type was less prevalent in the 1960s than at present.

Western Meadowlark (*Sturnella neglecta*) and Sprague’s Pipit are two grassland birds that feed and nest primarily in open grassland (Maher 1973). Numbers of Western Meadowlark have declined somewhat ($r_s = -0.637$, $P = 0.004$) averaging 0.21 pairs/ha or 3.91 pairs at the plot since 1968 (Figure 1d). BBS data indicate an annual decline of 2.62% in southern Saskatchewan (Environment Canada 2014). Sprague’s Pipits were relatively common (0.27 pairs/ha or 5.0 pairs at the plot) in 1968–1970 (Karasiuk 1973) and 1987–1989 (Pylypec 1991) but since 2005 numbers declined tremendously ($r_s = -0.845$, $P < 0.001$) and the last territory at the plot was noted in 2010 (Figure 1e). The species has declined (–3.83% annually) also in southern Saskatchewan (Environment Canada 2014). Sprague’s Pipit is listed as threatened (SARA Registry 2017).

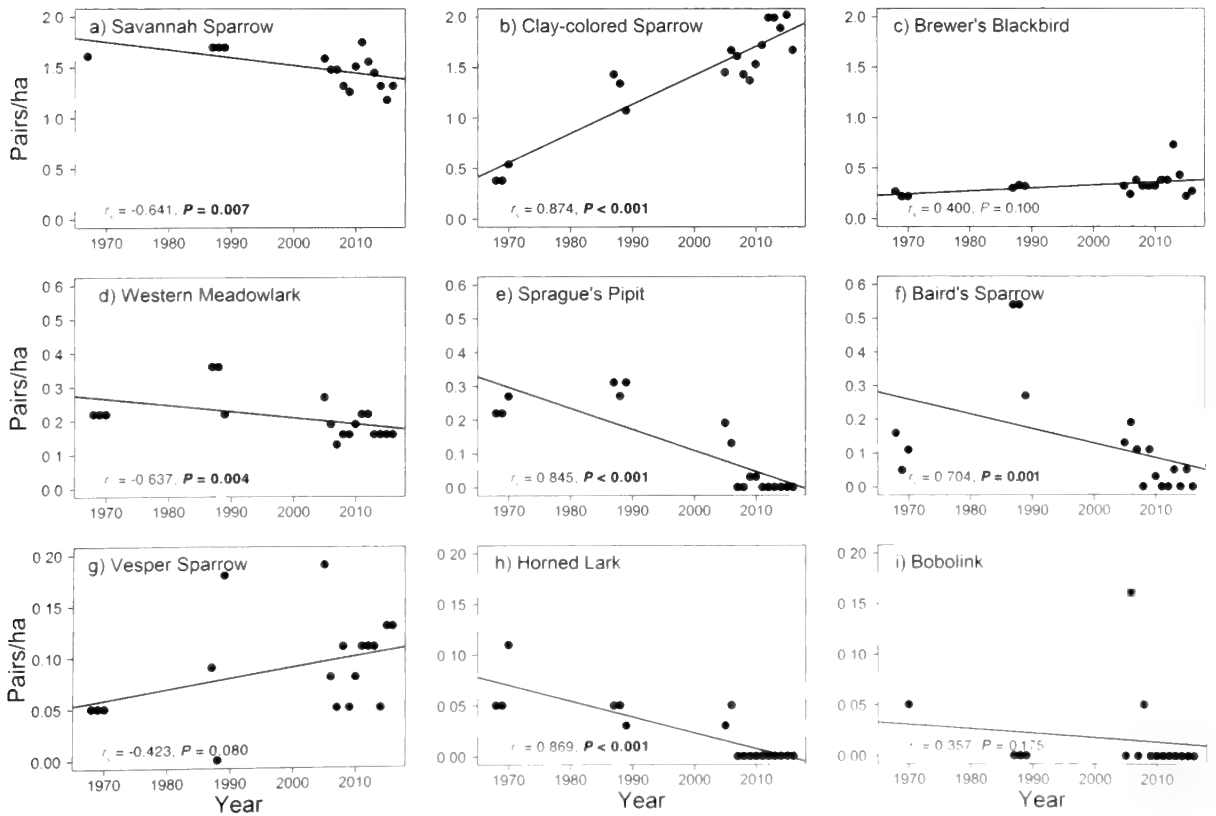


FIGURE 1. Breeding bird densities at Kernen Prairie: 1966–1970 (Lein 1968; Karasiuk 1973), 1987–1989 (Pylypec 1991), and 2005–2016. Spearman’s non-parametric correlation coefficients between year and the abundance of each species (r_s) and P -values are indicated; bold P -values are significant following a Bonferroni correction for multiple tests (0.05/9 = 0.0055).

Baird's Sparrow is another passerine that feeds and nests in open grassland with a thick vegetative canopy (Lein 1968; Maher 1973). This species does not occur in grassland that been heavily grazed, recently burned, or in cultivated areas. The species is "uncommon" in the Saskatoon area (Leighton *et al.* 2002). At the Kernen Prairie highest densities (0.54 pairs/ha) were noted in 1987 and 1988 (Pylypec 1991) but since 2008 it has been observed in very low numbers and was absent in five of nine years ($r_s = -0.704$, $P = 0.001$; Figure 1f). BBS data indicate the species declining 1.85% annually in southern Saskatchewan (Environment Canada 2014). The species is listed as a species of special concern (SARA Registry 2017).

Vesper Sparrow (*Poocetes gramineus*) numbers were relatively low (averaged 0.09 pairs/ha) but were consistent over the past 50 years (Figure 1g). In southern Saskatchewan, the species has increased annually (0.595%) during 1970–2012 (Environment Canada 2014). Vesper Sparrow is an "edge species" typically occupying fence lines between cultivated fields and native grassland (Owens and Myres 1973) but at Kernen Prairie it was also present in ecotonal areas around dense brush patches and aspen bluffs.

Horned Lark (*Eremophila alpestris*) is a grassland bird whose preferred habitat is grazed native grassland as opposed to "ungrazed" grassland (Maher 1973; Owens and Myres 1973). It also is the only passerine species in fescue grasslands of Alberta that uses cultivated land to any degree (Owens and Myres 1973). At Kernen Prairie the species was present at low numbers (0.05 pairs/ha) in 1968–1970 (Karasiuk 1973), 1987–1989 (Pylypec 1991), and 2005–2006 (Figure 1h). Since 2007 the species was absent at the native grassland ($r_s = -0.869$, $P < 0.001$) but a few individuals were noted in an adjacent cultivated field. In southern Saskatchewan, BBS data indicate a large annual decline (–4.39%) from 1970 to 2012 (Environment Canada 2014).

Two uncommon non-passerine birds of note have nested at Kernen Prairie in the past but are no longer present. Burrowing Owl, listed as endangered (SARA Registry 2017), was recorded as a resident on the prairie in 1966 and 1967 (Lein 1968). Two pairs were last noted in 1980, and the last pair in the area nested 1 km from the prairie in 1982. The species was not recorded in 1987–1989 (Pylypec 1991) or in 2005–2016. Upland Sandpiper (*Bartramia longicauda*), an uncommon summer resident in the Saskatoon area (Leighton *et al.* 2002), nested on the plot in 1988 and was last observed in 1989 (Pylypec 1991). It was not recorded in 2005–2016. However, in southern Saskatchewan BBS data indicate an annual increase of 4.18% (Environment Canada 2014).

Two additional non-passerine birds listed under SARA (SARA Registry 2017) have been observed at the Kernen Prairie. Long-billed Curlew is an "uncommon summer resident" in the Saskatoon area (Leighton

et al. 2002) and is listed as a species of special concern. This study has only one record (28 June 2010). Loggerhead Shrike Prairie subspecies (*Lanius ludovicianus excubitorides*) is also an "uncommon summer resident" in the Saskatoon area (Leighton *et al.* 2002) and is listed as threatened (SARA Registry 2017). At Kernen Prairie it has been recorded as "irregular" in the past 50 years (Table 1). BBS data indicate the species declining 3.05% annually in southern Saskatchewan (Environment Canada 2014).

Bobolink was assessed as threatened in April 2010 but is not yet on Schedule 1 of SARA (SARA Registry 2017). The species was recorded nesting at Kernen Prairie in 1966 and 1970 (Karasiuk 1973; Leighton *et al.* 2002). Territorial birds were last observed in 2006 and 2008 (Figure 1i). Two males were observed 1 km from the prairie on 8 July 2011 but no birds were observed from 2012 to 2016. In southern Saskatchewan, an annual increase of 0.703% has been noted from 1970 to 2012 (Environment Canada 2014).

Lark Bunting also was assessed as threatened in April 2017 but is not yet on Schedule 1 of SARA (SARA Registry 2017). The species was last seen at Kernen Prairie in 1989 (Pylypec 1991). BBS data indicate significant annual decline (–5.76%) of the species in southern Saskatchewan in 1970–2012 (Environment Canada 2014).

A number of other species have been recorded as nesting at the prairie during the duration of this study (Table 1). Of note, several duck species: Mallard (*Anas platyrhynchos*), Northern Pintail (*Anas acuta*), Blue-winged Teal (*Anas discors*), and Gadwall (*Anas strepera*) have nested in dense vegetation even though no permanent wetlands are present at the prairie. Also, Sharp-tailed Grouse (*Tympanuchus phasianellus*) broods have been observed at the prairie, and a lek 200 m from the plot was used from 1987 to 2013.

One colonial species has nested in loose colonies at Kernen Prairie throughout the duration of this study. Crude density numbers of Brewer's Blackbird were 0.22–0.27 pairs/ha in 1968–1970 (Karasiuk 1973), 0.30–0.33 pairs/ha in 1987–1989 (Pylypec 1991), and 0.22–0.73 pairs/ha in 2005–2016 (Figure 1c).

Conclusions

Kernen Prairie has provided breeding habitat for a number of grassland bird specialists over the past 50 years. This remnant 130 ha fescue grassland has been surrounded by cultivated land for at least 75 years and in the past decade urban development has encroached. Vegetation structure and composition at the prairie has been affected by a number of invasive species, Smooth Brome in particular being prominent. The invasive plant species have decreased the quality of habitat for grassland birds as they utilize patches of Smooth Brome, for example, much less than areas dominated by native vegetation (e.g., Plains Rough Fescue or Western Snowberry). Current management of the prairie using prescribed burns and conservation grazing by

cattle is attempting to maintain the composition and structure of native vegetation at the site while also improving the habitat for birds and other animals. Isolation of this native grassland and land uses of surrounding areas probably have also impacted bird populations.

Numbers of Savannah Sparrow, Western Meadowlark, Brewer's Blackbird, and Vesper Sparrow have been stable over this time period and do not appear to have been affected significantly by management practices at the prairie and surrounding areas. In contrast, Clay-colored Sparrow numbers have increased since the 1960s. This may be attributed to an increase in the amount of shrubbery at the prairie that has provided more suitable habitat for the species. The increase in the amount of shrubbery over the last 50 years can probably be attributed to the lack of grazing by cattle since the 1960s to 2006, and low intensity grazing since then.

Horned Larks were last observed at the prairie in 2006. The species preferred habitat is "grazed native grassland" (Maher 1973; Owens and Myres 1973). Absence of the species on the prairie probably can be attributed to unsuitable habitat for the species due to the increase in shrubbery and dense graminoid vegetation.

Burrowing Owl, Sprague's Pipit, and Upland Sandpiper are no longer present at the prairie. All of these species are rare or uncommon in Saskatchewan (Smith 1996), and with the exception of Upland Sandpiper, have been assessed by COSEWIC and are listed as species at risk (SARA Registry 2017). Also listed (SARA Registry 2017) are Baird's Sparrow, Loggerhead Shrike Prairie subspecies, Long-billed Curlew, and Short-eared Owl; these species plus Bobolink and Lark Bunting (assessed but not listed) have been recorded as "irregular" summer residents. Absence or rarity of these species at the prairie probably can be attributed to its isolation as a native grassland surrounded by cropland and urban development. The prairie has been surrounded by cropland for at least the past 75 years. Until 2000 the city limits of Saskatoon were 5 km away. Urban development started 800 m from the prairie in 2010 and by 2015 had encroached to the prairie. Impacts of fragmentation of habitat on grassland birds have also been shown by other studies (e.g., Bakker *et al.* 2002; Ribic *et al.* 2009; Buxton and Benson 2016).

A number of studies (e.g., Herkert 1994; Knopf 1994; Askins *et al.* 2007; Henderson and Davis 2014) have documented the decline in grassland bird specialists in North American native grasslands (tall grass prairie, shortgrass prairie, and mixed prairie types) due to habitat loss. This long-term study documented similar declines of some species of grassland specialist birds at a remnant Fescue Prairie also impacted by encroachment of urban development and long-term habitat alteration.

Acknowledgements

I thank R. E. Redmann, J. T. Romo, and E. G. Lamb for their encouragement to conduct this long-term study. Special thanks to two anonymous reviewers for their helpful comments. The support of the Department of Plant Sciences, University of Saskatchewan is greatly appreciated.

Literature Cited

- Acton, D. E., G. A. Padbury, and C. T. Stushnoff. 1998. The ecoregions of Saskatchewan. Canadian Plains Research Centre, University of Regina, Regina, Saskatchewan, Canada.
- Arnold, T. W., and K. F. Higgins. 1986. Effects of shrub coverages on birds of North Dakota mixed-grass prairies. *Canadian Field-Naturalist* 100: 10–14.
- Askins, R., F. Chavez-Ramirez, B. C. Dale, C. A. Haas, J. F. Herkert, F. Knopf, and P. D. Vickery. 2007. Conservation of grassland birds in North America: understanding ecological processes in different regions. *Ornithological Monographs* 64: 1–46. <https://doi.org/10.2307/40166905>
- Baines, G. B. K. 1964. Plant distributions on a Saskatchewan prairie in relation to edaphic and physiographic factors. M.Sc. thesis, University of Saskatchewan, Saskatoon, Saskatchewan, Canada.
- Baines, G. B. K. 1973. Plant distributions on a Saskatchewan prairie. *Vegetatio* 28: 99–123. <https://doi.org/10.1007/BF02386216>
- Bakker, K. K., D. E. Naugle, and K. F. Higgins. 2002. Incorporating landscape models for migratory grassland bird conservation. *Conservation Biology* 16: 1638–1646. <https://doi.org/10.1046/j.1523-1739.2002.01328.x>
- Buxton, V. L., and T. J. Benson. 2016. Conservation-priority grassland bird response to urban landcover and habitat fragmentation. *Urban Ecosystems* 19: 599–613. <https://doi.org/10.1007/s11252-016-0527-3>
- Coupland, R. T. 1961. A reconsideration of grassland classification in the Northern Great Plains of North America. *Journal of Ecology* 49: 135–167. <https://doi.org/10.2307/2257431>
- Coupland, R. T., and T. C. Brayshaw. 1953. The Fescue Grassland in Saskatchewan. *Ecology* 34: 386–405. <https://doi.org/10.2307/1930904>
- Davis, J. 1965. The "singing male" method of censusing birds: a warning. *Condor* 67: 86–87.
- Davis, S. K. 2004. Area sensitivity in grassland passerines: effects of patch size, patch shape, and vegetation structure on bird abundance and occurrence in southern Saskatchewan. *The Auk* 121: 1130–1145. [https://doi.org/10.1642/004-8038\(2004\)121\[1130:ASIGPE\]2.0.CO;2](https://doi.org/10.1642/004-8038(2004)121[1130:ASIGPE]2.0.CO;2)
- Environment Canada. 2014. North American Breeding Bird Survey-Canada Trends, Data – version 2012. Accessed 3 September 2017. <https://wildlife-species.canada.ca/breeding-bird-survey-results>
- Forman, R. T. T. 1995. *Land Mosaics: The Ecology of Landscapes and Regions*. Cambridge University Press, London, United Kingdom.
- Gauthier, D. A., and E. B. Wiken. 2003. Monitoring the conservation of grassland habitats, Prairie Ecozone, Canada. *Environmental Monitoring and Assessment* 88: 343–364. <https://doi.org/10.1023/A:1025585527169>
- Grilz, P. L., and J. T. Romo. 1995. Management considerations for controlling smooth brome in fescue prairie. *Natural Areas Journal* 15: 148–156.

- Gross, D. V., and J. T. Romo.** 2010a. Temporal changes in species composition in fescue prairie: relationships with burning history, time of burning, and environmental conditions. *Plant Ecology* 208: 137–153. <https://doi.org/10.1007/s11258-009-9693-1>
- Gross, D. V., and J. T. Romo.** 2010b. Burning history, time of burning, and year effects on plant community structure and heterogeneity in fescue prairie. *Botany* 88: 1–12. <https://doi.org/10.1139/B09-091>
- Hammermeister, A., D. Gauthier, and K. McGovern.** 2001. Saskatchewan's Native Prairie: Statistics of a Vanishing Ecosystem and Dwindling Resource. Native Plant Society of Saskatchewan, Inc., Saskatoon, Saskatchewan, Canada.
- Henderson, A. E., and S. K. Davis.** 2014. Rangeland health assessment: a useful tool for linking range management and grassland bird conservation? *Rangeland Ecology and Management* 67: 88–98. <https://doi.org/10.2111/REM-D-12-00140.1>
- Herkert, J. R.** 1994. The effects of habitat fragmentation on midwestern grassland bird communities. *Ecological Applications* 4: 461–471. <https://doi.org/10.2307/1941950>
- Kantrud, H. A., and R. L. Kologiski.** 1982. Effects of Soils and Grazing on Breeding Birds of Uncultivated Upland Grasslands of the Northern Great Plains. United States Department of the Interior Fish and Wildlife Service. Wildlife Research Report 15. Washington, D.C., U.S.A.
- Karasiuk, D. J.** 1973. The feeding ecology of the savannah sparrow, *Passerculus sandwichensis* (Gmelin) at Saskatoon, Saskatchewan. M.Sc. thesis, University of Saskatchewan, Saskatoon, Saskatchewan, Canada.
- Kendeigh, S. C.** 1944. Measurement of bird populations. *Ecological Monographs* 14: 67–106. <https://doi.org/10.2307/1961632>
- Knapton, R. W.** 1978. Breeding ecology of the clay-colored sparrow. *The Living Bird* 17: 137–158.
- Knopf, F. L.** 1994. Avian assemblages on altered grasslands. Pages 247–257 in *A Century of Avifaunal Change in Western North America. Proceedings of an International Symposium at the Centennial Meeting of the Cooper Ornithological Society*. Edited by J. R. Jehl, Jr. and N. K. Johnson. Studies in Avian Biology, No. 15, Sacramento, California, USA.
- Leighton, A. L., J. Hay, C. S. Houston, J. F. Roy, S. Shadick, and M. Gilliland.** 2002. Birds of the Saskatoon area. Saskatchewan Natural History Society (Nature Saskatchewan) Special Publication no. 23, Saskatoon, Saskatchewan, Canada.
- Lein, M. R.** 1968. The breeding biology of the savannah sparrow, *Passerculus sandwichensis* (Gmelin) at Saskatoon, Saskatchewan. M.Sc. thesis, University of Saskatchewan, Saskatoon, Saskatchewan, Canada.
- Madden, E. M., R. K. Murphy, A. J. Hansen, and L. Murray.** 2000. Models for guiding management of prairie bird habitat in northwestern North Dakota. *American Midland Naturalist* 144: 377–392. [https://doi.org/10.1674/0003-0031\(2000\)144\[0377:MFGMOP\]2.0.CO;2](https://doi.org/10.1674/0003-0031(2000)144[0377:MFGMOP]2.0.CO;2)
- Maher, W. J.** 1973. Birds: I. Population dynamics. Canadian Committee for the International Biological Programme (Matador Project) Technical Report no. 34. University of Saskatchewan, Saskatoon, Saskatchewan, Canada.
- Mori, N.** 2009. Composition and structure of fescue prairie respond to burning and environmental conditions more than to grazing or burning and grazing in the short-term. M.Sc. thesis, University of Saskatchewan, Saskatoon, Saskatchewan, Canada.
- Otfinowski, R., N. C. Kenkel, and P. M. Catling.** 2007. The biology of Canadian weeds. 134. *Bromus inermis* Leyss. *Canadian Journal of Plant Science* 87: 183–198. <https://doi.org/10.4141/P06-071>
- Owens, R. A., and M. T. Myres.** 1973. Effects of agriculture upon populations of native passerine birds of an Alberta fescue grassland. *Canadian Journal of Zoology* 51: 697–713. <https://doi.org/10.1139/z73-104>
- Pylypec, B.** 1986. The Kernen Prairie—a relict fescue grassland near Saskatoon, Saskatchewan. *Blue Jay* 44: 222–231.
- Pylypec, B.** 1991. Impacts of fire on bird populations in a fescue prairie. *Canadian Field-Naturalist* 105: 346–349.
- R Development Core Team.** 2016. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
- Ribic, C. A., R. R. Koford, J. R. Herkert, D. H. Johnson, N. D. Niemuth, D. E. Naugle, K. K. Bakker, D. W. Sample, and R. B. Renfrew.** 2009. Area sensitivity in North American grassland birds: patterns and processes. *The Auk* 126: 233–244. <https://doi.org/10.1525/auk.2009.1409>
- Romo, J. T.** 2003. Reintroducing fire for conservation of Fescue Prairie Association remnants in the Northern Great Plains. *Canadian Field-Naturalist* 117: 89–99.
- Roy, J. F.** 1996. Birds of the Elbow. Saskatchewan Natural History Society Special Publication no. 21. Nature Saskatchewan, Regina, Saskatchewan, Canada.
- Sampson, F., and F. Knopf.** 1994. Prairie conservation in North America. *BioScience* 44: 418–421. <https://doi.org/10.2307/1312365>
- SARA (Species at Risk Act) Registry.** 2017. Species at risk public registry. Accessed 9 August 2017. http://sararegistry.gc.ca/sar/assessment/status_e.cfm
- Saskatoon Nature Society.** 2010. Saskatoon Area Birds: a Seasonal Checklist. Nature Saskatchewan, Regina, Saskatchewan, Canada.
- Smith, A. R.** 1996. Atlas of Saskatchewan Birds. Saskatchewan Natural History Society (Nature Saskatchewan) Special Publication no. 22, Nature Saskatchewan, Regina, Saskatchewan, Canada.

Received 6 October 2016

Accepted 28 August 2017

Thematic Collection

The Canadian Field-Naturalist, Documenting Species New to Canada for Nearly a Century

AMANDA E. MARTIN

Geomatics and Landscape Ecology Laboratory, Carleton University, 1125 Colonel By Drive, Ottawa, Ontario K1S 5B6 Canada; email: Amanda.Martin@glel.carleton.ca

Martin, Amanda E. 2017. Thematic Collection: *The Canadian Field-Naturalist*, documenting species new to Canada for nearly a century. *Canadian Field-Naturalist* 131(2): 179–186. <https://doi.org/10.22621/cfn.v131i2.1989>

There are many reasons why a species not previously known to occur in Canada is subsequently found there. For example, species distributions may shift due to climate change, moving the upper limit of the species' range northward into Canada (Chen *et al.* 2011). Species not native to Canada may also be introduced – either intentionally or by accident – from other parts of the world. Observations of species in areas previously thought to be outside the species' distributions may also occur simply because the field biologist is in the right place at the right time to observe a cryptic species, or because new surveys occurred in areas not previously studied.

The Canadian Field-Naturalist (CFN) has played an important role documenting observations of species new to Canada¹, and has been adding to the known flora and fauna of Canada for nearly a century. This is due, at least in part, to its long and continuous publication history, and its focus on the natural history of Canadian species. CFN has to date published 99 volumes, starting in 1919². In total, this Thematic Collection includes 163 articles published in CFN, each documenting the first known observation of a given species (or subspecies) in Canada (Figure 1). The earliest documented the first observation of the Common Morel (*Morchella esculenta* (L.) Pers.) in Canada (Odell 1920), while the most

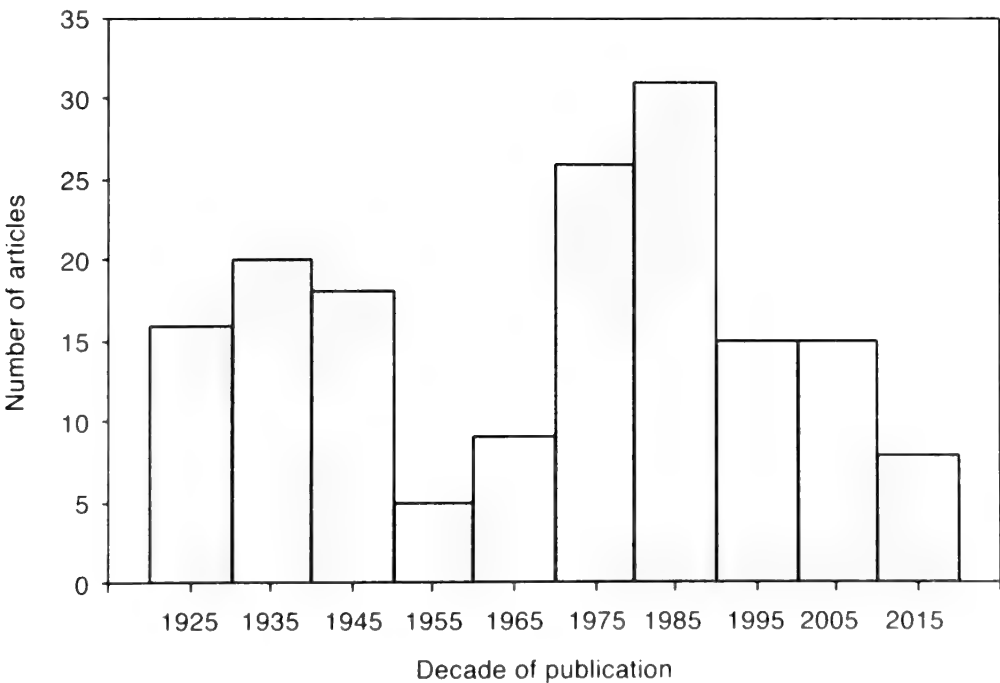


FIGURE 1. Number of articles documenting the first observation of a species (or subspecies) in Canada published in *The Canadian Field-Naturalist* since its inception in 1919.

¹The general goal of the Thematic Collection is to highlight published contributions to both CFN and the Ottawa Field-Naturalists' Club's (OFNC's) regional publication, *Trail & Landscape*, on a given theme. However, in this Collection I have included only publications in CFN, because my focus was on articles identifying new species at a national, rather than regional, extent.

²Prior to 1919, the OFNC published *The Ottawa Naturalist*. Its first issue was published in 1887, and 32 volumes were published by the OFNC under this name. Publication of *The Ottawa Naturalist* ceased with the first issue of CFN. The first issue of CFN began at volume 33.

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalists' Club.

recent documented the first known occurrence of a Pacific Angel Shark (*Squatina californica*) off the coast of British Columbia (King and Surrey 2016). This collection of articles includes a broad array of taxa, including fungi (Odell 1920), lichens (Lewis 2010), plants (Duncan 1973), arachnids (Klugh 1920), insects (Morris 1986), molluscs (Te and Clarke 1985), fishes (Sylvester *et al.* 2005), mammals (Cowan 1945), birds (Taverner 1934), amphibians (Uzzell 1962), and reptiles (Sternberg 1932), and articles on both extant and long-extinct species (identified by their fossil remains; Gilmore 1923).

Understanding what species occur in Canada (and where) is an important first step in their conservation and management. For example, this Thematic Collection includes CFN articles documented the first known observations of species now listed as endangered in Canada and protected under the *Species at Risk Act*, including Hotwater Physa (*Physella wrighti*; Te and Clarke 1985; SARA Registry 2017a), Small-mouthed Salamander (*Ambystoma texanum*; Uzzell 1962; SARA Registry 2017b), and Tri-colored Bat (*Perimyotis subflavus*; Saunders 1920; SARA Registry 2017c). CFN has also documented the first known occurrences of invasive species such as Kudzu (*Pueraria montana* (Lour.) Merr.; Waldron and Larson 2012) which is considered to be one of the top 100 worst invasive species in the world (Global Invasive Species Database 2017). This Kudzu population is now being managed by the Canadian Food Inspection Agency (CFIA 2017).

The known flora and fauna of Canada are likely to continue to change, and at increasingly rapid rates. For example, Canada is likely to gain species as their distributions rapidly shift northward in response to climate change. In their global meta-analysis, Chen *et al.* (2011) found that species ranges were shifting to higher latitudes at a median rate of 17 km/decade. Rates of species invasions have also been increasing over time (Hulme 2009), suggesting that there will be an increasing number of non-native species to discover in Canada in the future. Thus, we expect that CFN will continue its important role documenting observations of species new to Canada, contributing to our knowledge of Canadian species and to their conservation and management.

Literature Cited (Not Including Those in the Collection of Papers)

- CFIA (Canadian Food Inspection Agency).** 2017. Invasive plants fact sheet, Kudzu – *Pueraria montana*. Accessed 4 September 2017. <http://www.inspection.gc.ca/plants/plant-pests-invasive-species/invasive-plants/fact-sheets/kudzu/eng/1331750489827/1331750551292>.
- Chen, I.-C., J. K. Hill, R. Ohlemüller, D. B. Roy, and C. D. Thomas.** 2011. Rapid range shifts of species associated with high levels of climate warming. *Science* 333: 1024–1026. <https://doi.org/10.1126/science.1206432>
- Global Invasive Species Database.** 2017. 100 of the world's worst invasive alien species. Accessed 3 September 2017. http://www.iucngisd.org/gisd/100_worst.php.
- Hulme, P. E.** 2009. Trade, transport and trouble: managing invasive species pathways in an era of globalization. *Journal of Applied Ecology* 46: 10–18. <https://doi.org/10.1111/j.1365-2664.2008.01600.x>
- SARA (Species at Risk) Registry.** 2017a. Species profile, Hotwater Physa. Accessed 15 September 2017. http://www.registrelep-sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=548.
- SARA (Species at Risk) Registry.** 2017b. Species profile, Small-mouthed Salamander. Accessed 3 September 2017. http://www.registrelep-sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=284.
- SARA (Species at Risk) Registry.** 2017c. Species profile, Tri-colored Bat. Accessed 3 September 2017. http://www.registrelep-sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=1174.
- Collection of Papers (in Chronological Order)**
- Odell, W. S.** 1920. A rare fungus new to Canada. *Canadian Field-Naturalist* 34:10–13. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/17534#page/181mode/1up>.
- Saunders, W. E.** 1920. A new mammal for Canada. *Canadian Field-Naturalist* 34: 17. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/17534#page/25mode/1up>.
- Klugh, A. B.** 1920. A spider new to Canada. *Canadian Field-Naturalist* 34: 100. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/17534#page/108mode/1up>.
- Cox, P.** 1921. A cyprinid new to science. *Canadian Field-Naturalist* 35: 66–67. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/17469#page/74mode/1up>.
- Johansen, F.** 1921. A fairy-shrimp new to Canada and western North America. *Canadian Field-Naturalist* 35: 132–133. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/17469#page/140mode/1up>.
- Glendenning, R.** 1922. Addition to the Canadian flora *Cephalanthera oregana* Reich. *Canadian Field-Naturalist* 36: 119. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/17564#page/129mode/1up>.
- Newcombe, C. F.** 1922. Addition to the flora of Canada. *Canadian Field-Naturalist* 36: 120. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/17564#page/130mode/1up>.
- Johansen, F.** 1922. A freshwater-isopod new to Canada. *Canadian Field-Naturalist* 36: 156. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/17564#page/168mode/1up>.
- Klugh, A. B.** 1922. A cladoceran new to America. *Canadian Field-Naturalist* 36: 156. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/17564#page/168mode/1up>.
- Gilmore, C. W.** 1923. A new species of *Corythosaurus* with notes on other Belly River Dinosauria. *Canadian Field-Naturalist* 37: 46–52. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89324#page/74mode/1up>.
- Clark, T. H.** 1923. A group of new species of *Agnostus* from Lévis, Quebec. *Canadian Field-Naturalist* 37: 121–125. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89324#page/201mode/1up>.
- Cox, P.** 1924. New and rare records of certain freshwater fishes in Canada. *Canadian Field-Naturalist* 38: 85–86.

- Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89061#page/129/mode/1up>.
- Tufts, R. W.** 1925. Record of the Sooty Tern for Nova Scotia. Canadian Field-Naturalist 39: 64. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89256#page/94/mode/1up>.
- Klugh, A. B.** 1926. Notes on Canadian freshwater Entomostraca. Canadian Field-Naturalist 40: 133–135. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89074#page/171/mode/1up>.
- Clark, T. H.** 1928. A new cephalopod from the Trenton limestone of Montreal. Canadian Field-Naturalist 42: 187–189. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89279#page/261/mode/1up>.
- Allin, A. E.** 1930. Extension of range of *Esox americanus* (Gmelin). Canadian Field-Naturalist 44: 21. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89659#page/31/mode/1up>.
- Russell, L. S.** 1932. New species of Mollusca from the St. Mary River Formation of Alberta. Canadian Field-Naturalist 46: 80–81. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89295#page/102/mode/1up>.
- Sternberg, C. M.** 1932a. Two new theropod dinosaurs from the Belly River Formation of Alberta. Canadian Field-Naturalist 46: 99–105. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89295#page/125/mode/1up>.
- Sternberg, C. M.** 1932b. A new fossil crocodile from Saskatchewan. Canadian Field-Naturalist 46: 128–133. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89295#page/158/mode/1up>.
- Russell, L. S.** 1933. A new species of *Merychippus* from the Miocene of Saskatchewan. Canadian Field-Naturalist 47: 11. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89103#page/21/mode/1up>.
- Taverner, P. A.** 1934. The Madeira Petrel, *Oceanodroma castro*—a new bird for Canada. Canadian Field-Naturalist 48: 20–21. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89299#page/28/mode/1up>.
- Baker, F. C.** 1934a. Description of a new species of *Gyraultus*. Canadian Field-Naturalist 48: 37. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89299#page/49/mode/1up>.
- Groh, H.** 1934. *Ajuga genevensis* L. Erect Bugle, in Canada. Canadian Field-Naturalist 48: 102. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89299#page/132/mode/1up>.
- Anderson, R. M.** 1934. *Sorex palustris brooksi*, a new water shrew from Vancouver Island. Canadian Field-Naturalist 48: 134. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89299#page/172/mode/1up>.
- Baker, F. C.** 1934b. A new species of *Gyraultus* from Canada. Canadian Field-Naturalist 48: 135. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89299#page/173/mode/1up>.
- Templeman, W.** 1934. Record of *Ovalipes ocellatus* (Herbst) from Gulf of St. Lawrence. Canadian Field-Naturalist 48: 144. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89299#page/186/mode/1up>.
- Ferguson, M. S.** 1935. Three species of *Eubranchipus* new to Canada. Canadian Field-Naturalist 49: 47–49. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89293#page/63/mode/1up>.
- Connors, I. L.** 1937. Additions to the fungus flora of Anticosti Island and Gaspé Peninsula. Canadian Field-Naturalist 51: 6–7. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89331#page/14/mode/1up>.
- Dore, W. G.** 1937. *Holcus mollis* in Canada. Canadian Field-Naturalist 51: 77–78. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89331#page/101/mode/1up>.
- McLearn, F. H.** 1937. New species from the Triassic Schooler Creek Formation. Canadian Field-Naturalist 51: 95–98. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89331#page/127/mode/1up>.
- Wilson, A. E.** 1938. Correlation of the Timiskaming outlier with description of a new cephalopod. Canadian Field-Naturalist 52: 1–3. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89087#page/11/mode/1up>.
- Groh, H.** 1939. Recent range extensions in plants. Canadian Field-Naturalist 53: 39–40. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89322#page/57/mode/1up>.
- Medcof, J. C.** 1939. On the occurrence of the terrestrial isopod *Androniscus dentiger*, in Canada. Canadian Field-Naturalist 53: 115. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89322#page/153/mode/1up>.
- Brown, M. S.** 1940. *Utricularia inflata* in Canada. Canadian Field-Naturalist 54: 44. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89073#page/60/mode/1up>.
- McLearn, F. H.** 1940a. New Canadian Triassic Ammonoids. Canadian Field-Naturalist 54: 47–51. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89073#page/69/mode/1up>.
- McLearn, F. H.** 1940b. Preliminary study of some Triassic Pelecypods and Ammonoids from the Peace River Foothills, B.C. Canadian Field-Naturalist 54: 111–116. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89073#page/155/mode/1up>.
- McLearn, F. H.** 1941. Preliminary descriptions of some new Triassic Pelecypods from the Peace River Foothills, B.C. Canadian Field-Naturalist 55: 31–33. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89100#page/49/mode/1up>.
- Mousley, H.** 1941a. A distinctive new variety of *Orchis Rotundifolia* from Canada: *Orchis Rotundifolia* Banks n. var. *Lineata*. Canadian Field-Naturalist 55: 64–65. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89100#page/92/mode/1up>.
- Mousley, H.** 1941b. Two orchids new to the province of Quebec and the Dominion of Canada, *Spiranthes vernalis* Engelm. & Gray and *Spiranthes cernua* (L.) L. C. Rich. var. *odorata* (Nutt.) Correll. Canadian Field-Naturalist 55: 79–80. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89100#page/115/mode/1up>.
- Anderson, R. M.** 1942. Canadian voles of the genus *Phenacomys* with description of two new Canadian subspecies. Canadian Field-Naturalist 56: 56–60. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89066#page/80/mode/1up>.
- Anderson, R. M., and A. L. Rand.** 1943. A new lemming mouse (*Synaptomys*) from Manitoba with notes on some other forms. Canadian Field-Naturalist 57: 101–103. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89043#page/123/mode/1up>.
- Sinclair, G. W.** 1943. A new genus of conularids. Canadian Field-Naturalist 57: 123. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89043#page/123/mode/1up>.

- [//www.biodiversitylibrary.org/item/89043#page/151/mode/1up](http://www.biodiversitylibrary.org/item/89043#page/151/mode/1up).
- Anderson, R. M., and A. L. Rand.** 1945a. A new form of Dusky Shrew from the Prairie provinces of Canada. *Canadian Field-Naturalist* 59: 47–48. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89174#page/61/mode/1up>.
- Anderson, R. M., and A. L. Rand.** 1945b. A new shrew from arctic North America. *Canadian Field-Naturalist* 59: 62–64. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89174#page/78/mode/1up>.
- Cowan, I. M.** 1945. The Free-tailed Bat, *Tadarida macrotis*, in British Columbia. *Canadian Field-Naturalist* 59: 149. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89174#page/175/mode/1up>.
- Porsild, M. P.** 1946. A new *Antennaria* from Whitehorse, Yukon. *Canadian Field-Naturalist* 60: 85. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/90257#page/115/mode/1up>.
- Rand, A. L.** 1946. A new race of purple finch *Carpodacus purpureus* (Gmelin). *Canadian Field-Naturalist* 60: 95–96. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/90257#page/129/mode/1up>.
- Cowan, I. M., and K. Racey.** 1946. A new pika (genus *Ochotona*) from British Columbia. *Canadian Field-Naturalist* 60: 102–104. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/90257#page/136/mode/1up>.
- Dore, W. G.** 1947. *Glyceria maxima* in Canada. *Canadian Field-Naturalist* 61: 174. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89250#page/198/mode/1up>.
- Boivin, B.** 1948. Two new *Thalictra* from western Canada. *Canadian Field-Naturalist* 62: 167–169. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89251#page/203/mode/1up>.
- Porsild, A. E.** 1949. A new *Antennaria* from northern Ungava. *Canadian Field-Naturalist* 63: 80–81. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89254#page/94/mode/1up>.
- Porsild, A. E.** 1950. Five new Compositae from Yukon – Alaska. *Canadian Field-Naturalist* 64: 43–45. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89246#page/55/mode/1up>.
- Godfrey, W. E.** 1950. Description of a new northwestern *Geothlypis*. *Canadian Field-Naturalist* 64: 104. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89246#page/124/mode/1up>.
- Ferguson, R. G.** 1950. The first record of the Chiselmouth, *Acrocheilus alutaceus* Agassiz and Pickering, from British Columbia, Canada. *Canadian Field-Naturalist* 64: 156. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89246#page/180/mode/1up>.
- Stirrett, G. M.** 1952. Lawrence's Warbler in Canada. *Canadian Field-Naturalist* 66: 111. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89102#page/147/mode/1up>.
- Frankton, C.** 1954. A new weed, *Erysimum hieracifolium* L. in Canada. *Canadian Field-Naturalist* 68: 27–28. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89325#page/35/mode/1up>.
- Bousfield, E. L.** 1955. *Viviparus viviparus* L. in eastern Canada. *Canadian Field-Naturalist* 69: 27–28. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89330#page/37/mode/1up>.
- Klawe, W. L.** 1955. *Pseudomma affine* G. O. Sars: an addition to the list of the Mysidacea of eastern Canada. *Canadian Field-Naturalist* 69: 66. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89330#page/82/mode/1up>.
- Erskine, D.** 1955. Two red algae new to Nova Scotia. *Canadian Field-Naturalist* 69: 150–151. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89330#page/174/mode/1up>.
- Godfrey, W. E.** 1961. First Canadian record of the Black-throated Sparrow. *Canadian Field-Naturalist* 75: 162. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89075#page/180/mode/1up>.
- Uzzell, Jr., T. M.** 1962. The Small-mouthed Salamander, new to the fauna of Canada. *Canadian Field-Naturalist* 76: 182. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89328#page/196/mode/1up>.
- Porsild, A. E.** 1964. *Potentilla stipularis* L. and *Draba sibirica* (Pall.) Thell. new to North America. *Canadian Field-Naturalist* 78: 92–97. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89058#page/106/mode/1up>.
- Crum, H.** 1965. *Barbula eustegia* a moss new to Canada. *Canadian Field-Naturalist* 79: 157. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89098#page/169/mode/1up>.
- Walkinshaw, L. H.** 1965. A new Sandhill Crane from central Canada. *Canadian Field-Naturalist* 79: 181–184. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89098#page/197/mode/1up>.
- Bailey, K., and J. S. Bleakney.** 1966. First Canadian record of the brackish water anthozoan *Nematostella vectensis* Stephenson. *Canadian Field-Naturalist* 80: 251–252. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89101#page/267/mode/1up>.
- Taschereau, P. M.** 1969. Clethraceae: a plant family new to Canada. *Canadian Field-Naturalist* 83: 166. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89179#page/178/mode/1up>.
- McPhail, J. D.** 1969. Two rare sculpins (Cottidae) new to the marine fauna of British Columbia. *Canadian Field-Naturalist* 83: 400–401. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89179#page/416/mode/1up>.
- Fedoruk, A. N., J. J. Keleher, and D. C. Windsor.** 1970. First Canadian record of the Bigmouth Shiner, *Notropis dorsalis* (Agassiz). *Canadian Field-Naturalist* 84: 391–394. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/93459#page/425/mode/1up>.
- Pritchard, G.** 1971. *Argia vivida* Hagen (Odonata: Coenagrionidae) in hot pools at Banff. *Canadian Field-Naturalist* 85: 186–188. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89145#page/204/mode/1up>.
- Hatler, D. F.** 1971. A Canadian specimen of Risso's Dolphin. *Canadian Field-Naturalist* 85: 188–189. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89145#page/206/mode/1up>.
- Gillet, J. M.** 1971. *Cyperus fuscus* L. new to Canada. *Canadian Field-Naturalist* 85: 190. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89145#page/208/mode/1up>.
- Wyett, B.** 1971. First Canadian specimen of Bell's Vireo. *Canadian Field-Naturalist* 85: 327–328. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89145#page/355/mode/1up>.
- Campbell, R. W.** 1971. First Canadian specimen of New Zealand Shearwater. *Canadian Field-Naturalist* 85: 329–

330. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89145#page/357mode/1up>.
- Gilhen, J.** 1972. The White Mullet, *Mugil curema*, added to and the Striped Mullet, *M. cephalus*, deleted from the Canadian Atlantic Fish Fauna. Canadian Field-Naturalist 86: 74–77. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89146#page/86mode/1up>.
- Clarke, A. H.** 1972. *Clanculus microdon ater* Pilsbry in British Columbia. Canadian Field-Naturalist 86: 165–166. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89146#page/189mode/1up>.
- Montgomery, F. H., and J. K. Morton.** 1973. *Trichostema dichotomum* L. (Labiatae) new to Canada. Canadian Field-Naturalist 87: 63–64. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89175#page/75mode/1up>.
- Schroeder, G. J.** 1973. The lichen *Cetraria idahoensis* Esslinger from Canada. Canadian Field-Naturalist 87: 65–66. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89175#page/77mode/1up>.
- Duncan, T.** 1973. Three plant species new to Canada on Pelee Island: *Triosteum angustifolium* L., *Valerianella umbilicata* (Sull.) Wood, and *Valerianella intermedia* Dyal. Canadian Field-Naturalist 87: 261–265. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89175#page/285mode/1up>.
- Taylor, P. S., R. Salter, M. A. Gollop, and M. J. Taylor.** 1974. The Bluethroat, a new bird for Canada. Canadian Field-Naturalist 88: 85. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89181#page/95mode/1up>.
- Moore, M. I.** 1974. *Physcia lacinulata* Müll. Arg.: a new lichen for Canada. Canadian Field-Naturalist 88: 88–89. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89181#page/98mode/1up>.
- MacKenzie-Grieve, R. C., and J. B. Tatum.** 1974. Costa's Hummingbird, a new bird for Canada. Canadian Field-Naturalist 88: 91–92. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89181#page/101mode/1up>.
- Molnar, L.** 1975. New distribution data on two mosses, *Fissidens exilis* and *Thuidium pygmaeum*, in Quebec. Canadian Field-Naturalist 89: 324–325. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89096#page/342mode/1up>.
- Gilhen, J., C. G. Gruchy, and D. E. McAllister.** 1976. The Sheepshead, *Archosargus probatocephalus*, and the Feather Blenny, *Hypsoblennius hentzi*, two additions to the Canadian Atlantic ichthyofauna. Canadian Field-Naturalist 90: 42–46. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89149#page/52mode/1up>.
- Reznicek, A. A., and R. E. Whiting.** 1976. *Bartonia* (Gentianaceae) in Ontario. Canadian Field-Naturalist 90: 67–69. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89149#page/77mode/1up>.
- Godfrey, W. E.** 1976. Audubon's Shearwater, a species new for Canada. Canadian Field-Naturalist 90: 494. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89149#page/518mode/1up>.
- Catling, P. M.** 1976. *Spiranthes magnicamporum* Sheviak, an addition to the orchids of Canada. Canadian Field-Naturalist 90: 467–470. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89149#page/491mode/1up>.
- Crins, W. J., P. D. Pratt, and D. F. Brunton.** 1977. *Paspalum ciliatifolium*, a grass new to Canada from southwestern Ontario. Canadian Field-Naturalist 91: 422–424. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89182#page/448mode/1up>.
- Campbell, C. A., and A. A. Reznicek.** 1977. New vascular plant records on Pelee and East Sister Islands, Essex County, Ontario. Canadian Field-Naturalist 92: 384–390. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89182#page/410mode/1up>.
- Peden, A. E.** 1977. First record of Atka mackerel, *Pleurogrammus monopterygius* (Hexagrammidae), in British Columbia. Canadian Field-Naturalist 91: 175–176. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89182#page/189mode/1up>.
- Crossman, E. J., and J. H. Leach.** 1979. First Canadian record of a Flathead Catfish. Canadian Field-Naturalist 93: 179–180. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89186#page/195mode/1up>.
- Crossman, E. J., and S. J. Nepszky.** 1979. First Canadian record of the Black Buffalo (Osteichthyes: Catostomidae). Canadian Field-Naturalist 93: 304–305. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89186#page/326mode/1up>.
- Češka, A., and O. Češka.** 1980. Additions to the flora of British Columbia. Canadian Field-Naturalist 94: 69–74. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89247#page/79mode/1up>.
- Kott, L. S., and R. S. W. Bobbette.** 1980. *Isoetes eatonii*, a quillwort new for Canada. Canadian Field-Naturalist 94: 163–166. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89247#page/179mode/1up>.
- Maycock, P. F., D. R. Gregory, and A. A. Reznicek.** 1980. Hill's Oak (*Quercus ellipsoidal*) in Canada. Canadian Field-Naturalist 94: 277–285. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89247#page/299mode/1up>.
- Holm, E., and G. A. Coker.** 1981. First Canadian records of the Ghost Shiner (*Notropis buchanani*) and the Orangespotted Sunfish (*Lepomis humilis*). Canadian Field-Naturalist 95: 210–211. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89183#page/226mode/1up>.
- Smith, H. C.** 1981. First record for Canada of the bat mite *Spinturnix globosus* and a new host, *Myotis lucifugus*. Canadian Field-Naturalist 95: 206–207. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89183#page/222mode/1up>.
- DeGraaf, D. A.** 1981. First Canadian record of Bering Cisco (*Coregonus laurettae*) from the Yukon River at Dawson, Yukon Territory. Canadian Field-Naturalist 95: 365. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89183#page/387mode/1up>.
- Reznicek, A. A., and P. M. Catling.** 1982. Cyperaceae new to Canada from Long Point, Norfolk County, Ontario. Canadian Field-Naturalist 96: 184–188. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89040#page/200mode/1up>.
- Redhead, S. A., and P. M. Catling.** 1983. Two Sable Island fungi, *Peziza ammophila* and *Hygrocybe turunda*, new to Nova Scotia. Canadian Field-Naturalist 97: 102–103. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89042#page/112mode/1up>.
- Beese, W. J.** 1983. White Malaxis, *Malaxis monophyllos* var. *diphyllus*, an addition to the orchids of Canada from the Queen Charlotte Islands, British Columbia. Canadian Field-Naturalist 97: 215–216. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89042#page/229mode/1up>.

- Crossman, E. J., and R. C. Simpson.** 1984. Warmouth, *Lepomis gulosus*, a freshwater fish new to Canada. Canadian Field-Naturalist 98: 496–498. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89187#page/518/mode/1up>.
- Gilhen, J., and D. E. McAllister.** 1985. The Tripletail, *Lobotes surinamensis*, new to the fish fauna of the Atlantic coast of Nova Scotia and Canada. Canadian Field-Naturalist 99: 116–118. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89190#page/126/mode/1up>.
- Te, G. A., and A. H. Clarke.** 1985. *Physella* (*Physella*) *wrighti* (Gastropoda: Physidae) a new species of tadpole snail from Liard Hot Springs, British Columbia. Canadian Field-Naturalist 99: 295–299. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89190#page/313/mode/1up>.
- Britton, D. M., W. G. Stewart, and W. J. Cody.** 1985. *Cystopteris protrusa*, Creeping Fragile Fern, an addition to the flora of Canada. Canadian Field-Naturalist 99: 380–382. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89190#page/398/mode/1up>.
- Harms, V. L., J. H. Hudson, and G. F. Ledingham.** 1986. *Rorippa truncata*, the Blunt-fruited Yellow Cress, new for Canada, and *R. tenerrima*, the Slender Yellow Cress, in southern Saskatchewan and Alberta. Canadian Field-Naturalist 100: 45–51. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89211#page/55/mode/1up>.
- Preston, W. B.** 1986. The Great Plains Toad, *Bufo cognatus*, an addition to the herpetofauna of Manitoba. Canadian Field-Naturalist 100: 119–120. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89211#page/129/mode/1up>.
- Campbell, R. W.** 1986. First Canadian record of the Scrub Jay, *Aphelocoma coerulescens*. Canadian Field-Naturalist 100: 120–121. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89211#page/130/mode/1up>.
- Morris, R. F.** 1986. Notes on the occurrence of the Hornet Moth, *Sesia apiformis* (Lepidoptera: Sesiidae), new to Canada. Canadian Field-Naturalist 100: 253–254. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89211#page/267/mode/1up>.
- Prouse, N. J., and D. E. McAllister.** 1986. The Glacial Eel-spout, *Lycodes frigidus*, from the Arctic Canadian Basin, new to the Canadian ichthyofauna. Canadian Field-Naturalist 100: 325–329. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89211#page/343/mode/1up>.
- Cody, W. J., and W. L. Putman.** 1986. A hawk's-beard, *Crepis pulchra*, adventive in Ontario. Canadian Field-Naturalist 100: 376–377. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89211#page/394/mode/1up>.
- Coad, B. W.** 1986. The Shortbarbel Dragonfish, *Stomias brevibarbus*, new to the fish fauna of the Atlantic Coast of Canada. Canadian Field-Naturalist 100: 394–395. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89211#page/412/mode/1up>.
- Catling, P. M., and V. R. Brownell.** 1987. New and significant vascular plant records in Manitoba. Canadian Field-Naturalist 101: 437–439. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89248#page/453/mode/1up>.
- Crossman, E. J., S. J. Nepszy, and P. Krause.** 1987. The first record of Grass Carp, *Ctenopharyngodon idella*, in Canadian waters. Canadian Field-Naturalist 101: 584–586. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89248#page/604/mode/1up>.
- Hearne, M. E., and J. M. Cooper.** 1987. Aleutian Tern, *Sterna aleutica*, a new bird for Canada. Canadian Field-Naturalist 101: 589–590. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89248#page/609/mode/1up>.
- Morton, J. K.** 1988. Hedge Woundwort, *Stachys sylvatica* (Labiatae) in Canada. Canadian Field-Naturalist 102: 539–541. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89713#page/557/mode/1up>.
- Peden, A. E., and G. S. Jamieson.** 1988. New distributional records of marine fishes off Washington, British Columbia and Alaska. Canadian Field-Naturalist 102: 491–494. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89713#page/509/mode/1up>.
- Oldham, M. J., and W. J. Crins.** 1988. New and significant records of Ontario sedges (Cyperaceae). Canadian Field-Naturalist 102: 500–507. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89713#page/518/mode/1up>.
- Stewart, K. W.** 1988. First collections of the Weed Shiner, *Notropis texanus*, in Canada. Canadian Field-Naturalist 102: 657–660. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89713#page/679/mode/1up>.
- Madill, J.** 1988. New Canadian records of leeches (Annelida: Hirudinea) parasitic on fish. Canadian Field-Naturalist 102: 685–688. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/89713#page/707/mode/1up>.
- Gilhen, J., and D. E. McAllister.** 1989. The Atlantic Spanish Mackerel, *Scomberomorus maculatus*, new to Nova Scotia and Canada. Canadian Field-Naturalist 103: 287–289. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/106991#page/299/mode/1up>.
- Baird, R. W., K. M. Langelier, and P. J. Stacey.** 1989. First records of False Killer Whales, *Pseudorca crassidens*, in Canada. Canadian Field-Naturalist 103: 368–371. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/106991#page/384/mode/1up>.
- Donald, D. B.** 1989. First Canadian record for the clam shrimp *Caenestheriella belfragei* (Crustacea: Conchostraca). Canadian Field-Naturalist 103: 593–594. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/106991#page/613/mode/1up>.
- Kathman, R. D.** 1990. *Isohypsibius woodsae*, a new species of Eutardigrada (Tardigrada) from British Columbia. Canadian Field-Naturalist 104: 293–294. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/106989#page/305/mode/1up>.
- Ouellet, H.** 1990. A new Ruffed Grouse, Aves: Phasianidae: *Bonasa umbellus*, from Labrador, Canada. Canadian Field-Naturalist 104: 445–449. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/106989#page/461/mode/1up>.
- Cody, W. J., S. J. Darbyshire, and C. E. Kennedy.** 1990. A bluegrass, *Poa pseudoabbreviata* Roshev., new to the flora of Canada, and some additional records from Alaska. Canadian Field-Naturalist 104: 589–591. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/106989#page/609/mode/1up>.

- Britton, D. M., P. M. Catling, J. Norris, and S. Varga.** 1991. Engelmann's Quillwort, *Isoetes engelmannii*, an addition to the aquatic flora of Canada. *Canadian Field-Naturalist* 105: 67–70. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/106992#page/75> mode 1up.
- Ricciardi, A., and D. J. Lewis.** 1991. New records of freshwater leeches (Annelida: Hirudinea) from Quebec. *Canadian Field-Naturalist* 105: 368–371. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/106992#page/384> mode 1up.
- Crossman, E. J., E. Holm, R. Cholmondeley, and K. Tuininga.** 1992. First record for Canada of the Rudd, *Scardinus erythrophthalmus*, and notes on the introduced Round Goby, *Neogobius melanostomus*. *Canadian Field-Naturalist* 106: 206–209. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/106990#page/218> mode 1up.
- Sirois, J., and R. W. Butler.** 1994. First confirmed sighting of the Parakeet Auklet, *Cyclorhynchus psittacula*, in Canada. *Canadian Field-Naturalist* 108: 91–92. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/106813#page/99> mode 1up.
- Stacey, D. F., and B. R. Hubley.** 1994. New records of a sludge worm *Teneridrilus flexus* Erséus & Hiltunen (Oligochaeta: Tubificidae) from Lake Huron. *Canadian Field-Naturalist* 108: 182–185. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/106813#page/194> mode 1up.
- Gillespie, G. E., and M. W. Saunders.** 1994. First verified record of the Shortfin Mako Shark, *Isurus oxyrinchus*, and second records or range extensions for three additional species, from British Columbia waters. *Canadian Field-Naturalist* 108: 347–350. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/106813#page/363> mode 1up.
- Colt, Jr., L. C., R. A. Saumure, Jr., and S. Baskinger.** 1995. First record of the algal genus *Bacillaria* (Chlorophyta, Cladophorales) in Canada. *Canadian Field-Naturalist* 109: 454–455. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/109902#page/474> mode 1up.
- Brownell, V. R., C. S. Blaney, and P. M. Catling.** 1996. Recent discoveries of southern vascular plants at their northern limits in the granite barrens area of Lennox and Addington County, Ontario. *Canadian Field-Naturalist* 110: 255–259. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/106979#page/267> mode 1up.
- Waldron, G., M. Gartshore, and K. Colthurst.** 1996. Pumpkin Ash, *Fraxinus profunda*, in southwestern Ontario. *Canadian Field-Naturalist* 110: 615–619. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/106979#page/635> mode 1up.
- Oldham, M. J., and M. Zinck.** 1997. New and noteworthy records from the vascular flora of Nova Scotia. *Canadian Field-Naturalist* 111: 393–398. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/110182#page/41> mode 1up.
- Blaney, C. S., M. J. Oldham, and A. A. Reznicek.** 1997. Hyssop-leaved Loosestrife, *Lythrum hyssopifolia* L. (Lythraceae), new to Canada. *Canadian Field-Naturalist* 111: 664–665. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/110182#page/316> mode 1up.
- Di Maio, J., and D. F. Stacey.** 1998. New distribution records of aquatic Oligochaeta (Annelida) from running waters in Ontario. *Canadian Field-Naturalist* 112: 69–74. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/106776#page/77> mode 1up.
- Scott, G. W., and B. Zimmer.** 1998. Mountain Tassel-flower, *Soldanella montana* (Primulaceae), in Mount Robson Provincial Park, British Columbia. *Canadian Field-Naturalist* 112: 163–164. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/106776#page/171> mode 1up.
- Douglas, G. W., F. Lomer, and H. L. Roemer.** 1998. New or rediscovered native vascular plant species in British Columbia. *Canadian Field-Naturalist* 112: 276–279. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/106776#page/288> mode 1up.
- Gilhen, J., and B. W. Coad.** 1999. The False Catshark, *Pseudotriakis microdon* Brito Capello, 1867, new to the fish fauna of Atlantic Canada. *Canadian Field-Naturalist* 113: 514–516. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/106748#page/530> mode 1up.
- Nagorsen, D. W., G. G. E. Scudder, D. J. Huggard, H. Stewart, and N. Panter.** 2001. Merriam's Shrew, *Sorex merriami*, and Preble's Shrew, *Sorex preblei*: two new mammals for Canada. *Canadian Field-Naturalist* 115: 1–8. Accessed 3 September 2017. <http://www.biodiversitylibrary.org/item/108793#page/9> mode 1up.
- Gagnon, J.-M., and R. L. Haedrich.** 2003. First record of the European Giant File Clam, *Acesta excavata* (Bivalvia: Pectinoidea: Limidae), in the Northwest Atlantic. *Canadian Field-Naturalist* 117: 440–447. <https://doi.org/10.22621/cfn.v117i3.748>
- Gilhen, J., B. W. Coad, and A. Hebda.** 2003. The Chain Dogfish, *Scyliorhinus retifer* (Garman, 1881), new to the Canadian Atlantic Ichthyofauna. *Canadian Field-Naturalist* 117: 475–477. <https://doi.org/10.22621/cfn.v117i3.812>
- Pohl, G. R., D. W. Langor, J.-F. Landry, and J. R. Spence.** 2004. Moths and butterflies (Lepidoptera) of the boreal mixedwood forest near Lac La Biche, Alberta, including new provincial records. *Canadian Field-Naturalist* 118: 530–549. <https://doi.org/10.22621/cfn.v118i4.56>
- Gómez-Zurita, J.** 2005. New distribution records and biogeography of *Calligrapha* species (leaf beetles), in North America (Coleoptera: Chrysomelidae, Chrysomelinae). *Canadian Field-Naturalist* 119: 88–100. <https://doi.org/10.22621/cfn.v119i1.85>
- Ford, J. K. B.** 2005. First records of Long-beaked Common Dolphins, *Delphinus capensis*, in Canadian waters. *Canadian Field-Naturalist* 119: 110–113. <https://doi.org/10.22621/cfn.v119i1.88>
- Thomson, E. R.** 2005. Papillate Watermeal, *Wolffia brasiliensis*, in eastern Ontario: an addition to the flora of Canada. *Canadian Field-Naturalist* 119: 137–138. <https://doi.org/10.22621/cfn.v119i1.97>
- Sylvester, R. M., S. E. Freeling, and C. R. Berry, Jr.** 2005. First record of the Plains Minnow, *Hybognathus placius*, in Canada. *Canadian Field-Naturalist* 119: 219–223. <https://doi.org/10.22621/cfn.v119i2.436>
- Consaul, L. L., L. J. Gillespie, and K. I. MacInnes.** 2005. Addition to the flora of Canada? A specimen from the Arctic Archipelago, Northwest Territories links two allopatric species of alkali grass, *Puccinellia*. *Canadian Field-Naturalist* 119: 497–506. <https://doi.org/10.22621/cfn.v119i4.179>
- Boeckner, M. J., and H. C. Proctor.** 2005. Water-bears from the Rocky Mountains: a first look at Alberta's tardigrade fauna. *Canadian Field-Naturalist* 119: 586–588. <https://doi.org/10.22621/cfn.v119i4.193>

- Balkwill, D., B. W. Coad, I. Galvez, and J. Gilhen.** 2006. First record of the Great Barracuda, *Sphyræna barracuda*, from Canada. *Canadian Field-Naturalist* 120: 241–242. <https://doi.org/10.22621/cfn.v120i2.298>
- Cheney, M., and K. L. Marr.** 2007. Cowbane, *Oxypolis occidentalis*, a new native plant species for the Queen Charlotte Islands, British Columbia. *Canadian Field-Naturalist* 121: 421–422. <https://doi.org/10.22621/cfn.v121i4.515>
- Davy, C. M., K. C. Shim, and S. M. Coombes.** 2009. Leech (Annelida: Hirudinea) infestations on Canadian turtles, including the first Canadian record of *Helobdella modesta* from freshwater turtles. *Canadian Field-Naturalist* 123: 44–47. <https://doi.org/10.22621/cfn.v123i1.673>
- Bennett, B. A., P. M. Catling, W. J. Cody, and G. W. Argus.** 2010. New records of vascular plants in the Yukon Territory VIII. *Canadian Field-Naturalist* 124: 1–27. <https://doi.org/10.22621/cfn.v124i1.1025>
- Lewis, C.** 2010. *Psilolechia clavulifera*, a lichen species new to Canada. *Canadian Field-Naturalist* 124: 181–182. <https://doi.org/10.22621/cfn.v124i2.1058>
- Grothman, G. T.** 2011. Tardigrades of Fish Creek Provincial Park, Alberta, Canada: a preliminary survey. *Canadian Field-Naturalist* 125: 22–26. <https://doi.org/10.22621/cfn.v125i1.1117>
- Morris, C. J., B. W. Coad, and G. Fisher.** 2011. The Warty Dory, *Alloctytus verrucosus*, new to the fish fauna of Canada. *Canadian Field-Naturalist* 125: 74–75. <https://doi.org/10.22621/cfn.v125i1.1133>
- Heydon, P. A., G. C. Miller, and M. J. Oldham.** 2011. Hairy St. John's-wort (*Hypericum hirsutum* L.) in the Toronto area, new to North America. *Canadian Field-Naturalist* 125: 248–251. <https://doi.org/10.22621/cfn.v125i3.1228>
- Waldron, G. E., and B. M. H. Larson.** 2012. Kudzu Vine, *Pueraria montana*, adventive in southern Ontario. *Canadian Field-Naturalist* 126: 31–33. <https://doi.org/10.22621/cfn.v126i1.1292>
- Hanke, G. F., and S. M. Roias.** 2012. First specimens of the marine eels *Venefica ocella* and *V. tentaculata* (Nettastomatidae) from British Columbia. *Canadian Field-Naturalist* 126: 210–216. <https://doi.org/10.22621/cfn.v126i3.1362>
- Payette, A.** 2013. First record of the bee *Melitta americana* (Smith) (Hymenoptera: Melittidae) for Quebec and Canada. *Canadian Field-Naturalist* 127: 60–63. <https://doi.org/10.22621/cfn.v127i1.1409>
- McMullin, R. T., and J. C. Lendemer.** 2013. Lichen biodiversity and conservation status in the Copeland Forest Resources Management Area: a lichen-rich second-growth forest in southern Ontario. *Canadian Field-Naturalist* 127: 240–254. <https://doi.org/10.22621/cfn.v127i3.1490>
- King, J. R., and A. M. Surry.** 2016. First record of Pacific Angel Shark (*Squatina californica*) in Canadian Pacific waters. *Canadian Field-Naturalist* 130: 302–303. <https://doi.org/10.22621/cfn.v130i4.1922>

Received 7 September 2017

Accepted 12 September 2017

Book Reviews

Book Review Editor's Note: *The Canadian Field-Naturalist* is a peer-reviewed scientific journal publishing papers on ecology, behaviour, taxonomy, conservation, and other topics relevant to Canadian natural history. In line with this mandate, we review books with a Canadian connection, including those on any species (native or non-native) that inhabits Canada, as well as books covering topics of global relevance, including climate change, biodiversity, species extinction, habitat loss, evolution, and field research experiences.

Currency Codes – CAD Canadian Dollars, USD US Dollars, EUR Euros, AUD Australian Dollars, GBP British Pound.

BOTANY

Ancient Pathways, Ancestral Knowledge: Ethnobotany and Ecological Wisdom of Indigenous Peoples of Northwestern North America. Volume 1: The History and Practice of Indigenous Plant Knowledge. Volume 2: The Place and Meaning of Plants in Indigenous Cultures and Worldviews

By Nancy J. Turner. 2014. McGill-Queen's University Press. 1056 pages, 125.00 CAD, Cloth. Also available as an E-book.

Nancy Turner is without doubt among the pre-eminent ethnobotanists of our time. I first encountered her work in the early 1990s and, since then, I have often drawn on her publications as I undertake palaeoenvironmental research. She has strongly influenced my understanding of the role of plant use in Indigenous life-ways and how that might be reflected in postglacial palaeoecological records. So it was an especial pleasure for me to encounter these encyclopedic volumes that pull together threads from those earlier publications and present a comprehensive synthesis of her knowledge. Decades of thoughtful scholarship and collaboration with Indigenous people have gone into this work. It is magisterial in the true sense of that word: the distillation of a career's experience and learning.

Although split into two volumes, this work is a seamless whole. It discusses relationships among people, plants, and environments, with a focus on British Columbia and adjacent areas including the Yukon, panhandle Alaska, and Washington. From her base at the University of Victoria, Turner sets out her intent to investigate "people-plant relationships in northwestern North America in an effort to better understand the pathways and processes by which ethnobotanical and ethnoecological knowledge systems of Indigenous peoples in this area have developed, accumulated, spread, and evolved over time" (V1, p. 3). Following an introduction, the first volume explores the history (three chapters) and development (three chapters) of plant use by Indigenous people in western North America. The second volume discusses Indigenous peoples' integration and management (four chapters) and underlying philosophy (three chapters) of plant use.

Throughout her discussion, Turner emphasizes that this work builds "on the knowledge shared by numerous Indigenous cultural and botanical specialists" (V1, p. 5). Her Indigenous collaborators and informants are acknowledged and thanked while many also

share co-authorship on publications arising from this concerted work. The reference list includes 119 publications on which Turner is an author, including 83 on which she is first or sole author. The books are illustrated with black-and-white photographs, including many of plants discussed in the text, of plant-derived foods, and of tools used to harvest and process plant foods and materials. In several images, Elders show how to harvest and use plants and plant material. In others, children harvest berries (V2, p. 65) and gather edible seaweed (V2, p. 36), highlighting continuity and the living tradition of plant use.

Turner lists an impressive array of plants that have been used, and continue to be used, by Indigenous groups in northwest North America. At least 82 taxa are listed as "traditional plant foods" (V1, Table 5.1, pp. 270–278). The most numerous are roots or tubers (24 taxa) or berries (24 taxa). Plants in the Apiaceae, Fabaceae, Liliaceae, and Portulacaceae families feature prominently as sources for roots and tubers, while berry plants are predominantly drawn from the Rosaceae, Ericaceae, and Grossulariaceae families. There are 106 entries for "plant materials used in Indigenous technology" (V1, Table 6.1, pp. 339–345), and a further 174 entries for "medicinal plants" (V1, Table 7.1, p. 429). Trees and shrubs, especially from the Betulaceae, Cupressaceae, Rosaceae, Salicaceae, and Pinaceae families, are important sources for fibre and wood, both for fuel and construction. Some plant taxa appear more than once in each list. For example, Bearberry (*Arctostaphylos uva-ursi*) appears twice on the food list and three times for different medicinal applications. Useful plants are found in many habitats, from lowlands and wetlands (*Sagittaria latifolia*, *Typha latifolia*), to uplands and alpine slopes (*Oxyria digyna*, *Lewisia rediviva*). Many plants, such as Scouring Rush (*Equisetum hyemale*), Chokecherry (*Prunus virginiana*), and spruces (*Picea* spp.) appear on all three lists. Turner points out

that these lists are selective, not exhaustive, and indicates that “about 200 plant species are used, or have been used, medicinally in some way” (V1, p. 419), while 160 species have technological applications and 150 species have food uses.

There is much to ponder in these volumes. As a palaeoecologist, I was especially interested in the sections that discussed purposeful translocation and trading of plants and also landscape management techniques, such as controlled burning, that affected vegetation composition and distribution. These subjects are explored in depth in the second volume, where Turner reviews the use of plants as technology, as well as trade in plants among coastal and interior Indigenous groups. She gives many examples of plant management practices, including selective harvesting, partial harvesting that leaves most of the source plant intact, pruning (especially of berry bushes), and cultivation, such as aerating the soil by using digging sticks. Such practices require a thorough and sophisticated knowledge of plant biology and ecology. Moreover, they imply active intervention in the way in which plants are distributed across the landscape and their relative abundance in different localities. Turner is clear that “people systematically manipulated many different plant resources and habitats to enhance the productivity, reliability, and sustainability of the plants they used for food, materials, and medicines – that they, in fact, *cultivated* their environments and plant resources” (V1, p. 265). This is a very different perspective from that which posits that active landscape management in western Canada began when the first Euro-Canadian started to plough.

The take-home message here is that a distinction between “agricultural” and “hunter-gatherer” lifeways is too sharp a dichotomy (V1, p. 265). The plant and landscape management practices of Indigenous people that Turner describes are far from the passive acquiescence to environment that the word “gatherer” conjures up. She comments that the “stereotypical ‘hunter-gatherer’ paradigm is being increasingly challenged as more becomes known of Indigenous peoples’ often subtle but sometimes quite obvious manipulation of species and their environments” (V1, p. 265). This also reflects my understanding as I find the compartmentalism between “hunter-gatherer”, “horticulturalist”, and “agriculturalist” blurring. In my experience, the archaeological rec-

ord in western Canada privileges the “hunter” part of the “hunter-gatherer” lifeway, mainly because animal-derived food remains, such as bones, tend to be well-preserved and well-represented, whereas plant-derived food remains are not. Similarly, technology associated with hunting, such as stone projectile points, are also persistent in the archaeological record and have been used as the basis for distinguishing past cultural phases. In contrast, plant food remains or technology associated with plant food processing, such as gathering baskets or grinding stones, either do not preserve or have not, until recently, received the same attention from archaeologists. Today, new techniques, such as residue analysis, are being applied more frequently in research on artifacts and are revealing new details about plant use in the past. Turner also points out that the importance of plant foods may have been overlooked in the ethnographic record because “it is primarily ‘women’s work,’ and the majority of ethnographic information from the Indigenous cultures of the region was recorded by men of European background and culture” (V1, p. 265). Yet she cites research suggesting that for some groups in the interior, plant foods may have “contributed as much as 70 per cent of total dietary calories” (V1, p. 264). This emphasizes the importance of such plant foods to long-term community viability.

In this discussion, I have touched on only a few of the wide-ranging and important themes that weave throughout this study. Turner’s synthesis is dense, richly textured, and thought provoking. She writes lucidly and with great authority. This is not, however, a work to be tackled as a continuous narrative. I took several months to work through both volumes, savouring and thinking about each chapter. I found this an enjoyable and rewarding experience. My copies are now filled with marginal notes, underlined passages, and marker flags. I have no doubt that this synthesis will be one of my “go to” works as I continue my palaeoecological research. Nancy Turner offers valuable perspectives on plants of western Canada that complement and extend insights from biology and natural history. I highly recommend these volumes to anyone with an interest in Indigenous lifeways and plant use.

ALWYNNE B. BEAUDOIN

Royal Alberta Museum, Edmonton, AB, Canada

Some Useful Wild Plants: A Foraging Guide to Food and Medicine from Nature. Revised Edition

By Dan Jason. 2017. Harbour Publishing. 186 pages, 16.95 CAD, Paper.

First published over 45 years ago, *Some Useful Wild Plants* has been revised and reprinted, to help guide and inspire a new generation of foragers and amateur naturalists. The book is a cute, pocket-sized, casual reference guide to edible and medicinal plants found in British Columbia (BC). As the author points out in his

introduction, the book was expanded soon after its initial publication to contain species found elsewhere in BC, beyond the Slocan Valley, which was the focus of the first edition. In fact, many of the plants contained in this book are found throughout Canada and are familiar to this reviewer, who has spent all his time in Canada

in southern Ontario. (Incidentally, I am travelling tomorrow to BC for the first time – albeit a little late for this review!)

The book's format is simple and easy to digest, typically with each double-page spread containing a description of the habitat in which the species is found, key identification points, and how and when it flowers and/or fruits, in addition to how to utilize each plant for food (preparation, cooking methods, recipe ideas, and uses) and medicinal purposes. Each plant is also accompanied by the original and delightful line illustrations by the author's friend, Robert Inwood.

The medicinal use descriptions tend to be somewhat brief, but they do contain a wealth of information on potential uses and preparation methods, frequently incorporating examples of usage by First Nations people, gleaned first hand from interviews with "herbalists and Doukhobor wild-crafters" (p. 7). There are sufficient simple directions for the beginner herbalist, but I imagine these sections serve as a jumping off point for the serious medicinal forager, who would likely want to consult other resources to obtain more detailed preparation methods.

At first glance, the illustrations are very simple and I questioned their usefulness for positive identification. But further exploration makes one realize how well they fit this field guide and, coupled with an existing knowledge and/or interest in botany, they do provide sufficient key details when matched with the text to help guide oneself to a positive identification. There is not much in the way of technical botanical jargon, which is both a positive for the newcomer and a drawback for seasoned or serious plant nerds. Additionally, given the relatively narrow scope of the species detailed (this is not a comprehensive botanical guide), there is not much potential for confusion in identification. The illustrations have a simplistic beauty to them, which fits well with this guide overall.

The plants covered are organized conveniently into groups such as Herbs & Shrubs, Trees, Seaweeds, and Berries. There is also a rather essential section on Poisonous Plants which, despite containing the same de-

tailed botanical and life history information as the non-poisonous species, perhaps fails to incorporate much in the way of examples of, or links to, non-poisonous species with which they may be confused.

The section on Trees is particularly captivating. Many are species or at least genera with which many of us are familiar. What stands out here is the long list of food and, particularly, medicinal uses for the various parts of these trees, with which many of us are not familiar. Many of the species accounts also detail how to forage sustainably, with tips on how to support the continued growth of the plant. This is a key component of foraging practice which I am very grateful the author included.

Another feature of this book that I particularly enjoyed and found useful was the appendix, which conveniently groups species by their potential use – for example, for food uses, species are listed under "boiled", "candied", "ground for flour", etc. The medicinal uses are grouped by ailment or symptom you want to treat, and the appendix is nicely rounded off by a few "other uses" such as dyes, insect repellents, and soap.

Having not seen the original version of *Some Useful Wild Plants*, it was difficult to know what this revised edition has updated from the original, and the author doesn't detail this in the introduction. Regardless, this is a beautifully printed, accessible, and convenient pocket-sized guide, ideal for referencing in the field, perusing during mundane city commutes (whilst wishing you were in the wilderness!), during peaceful reflection time under a tree during a long hike, or whilst sheltering on a windswept BC beach (I would imagine!). However, to fully embrace foraging for both food and medicinal purposes, and to be 100% sure of what you are consuming or using, I suggest that this guide be accompanied by conventional botanical field guides for plants, shrubs, or trees. Regardless, this serves as an excellent introduction to plant foraging in both BC and throughout Canada.

MATTHW ILES

Assistant Program Coordinator, Long Point Bird Observatory,
Port Rowan, ON, Canada

ZOOLOGY

Birdmania: A Remarkable Passion for Birds

By Bernd Brunner. 2017. Translated by Jane Billingham from the 2015 German edition. Greystone Books. 292 pages. 39.95 CAD, Cloth.

This is a book of trivia ostensibly about the fantastical creatures we know as birds, but mostly about some of the fanatical humans who have wondered about, observed, tracked, caged, killed, and protected them over the centuries.

The 19 chapters are arranged somewhat chronologically, starting with the early Greeks and Romans, through the Medieval Period and the Age of Enlight-

enment to modern times. It also roughly traces the evolution of bird knowledge from the hypothesis (for example) that birds lacked kidneys and that any excess fluid in their system was directed to the formation of feathers, not urine (put forward by Aristotle), to the rudimentary beginnings of rigorous observation that laid the groundwork for scientific understanding of the lives of birds. There are fewer character sketches from

the late 20th century or this century; perhaps because modern scientists are not quirky enough? Or, more likely, they are still alive and it is more difficult to write about their eccentricities!

However, there are really no linkages between chapters and most chapters are quite short, so one can pick up the book and read a chapter, or even part of a chapter, at random because some of the character sketches are only a paragraph or two long. I did find the two longest chapters quite repetitive, with too many similar examples: Chapter 8, "In the company of birds", mostly chronicles numerous people who associated with individual birds, sometimes for decades, or who owned hundreds or thousands of birds in aviaries, while Chapter 11, "To kill or not to kill", became a litany of slaughter. While the author does include some well-known bird devotees such as Alexander Wilson and John James Audubon, he dug deep into the archives to introduce many lesser-known amateurs and professionals. How-

ever, the "selected bibliography and source of quotes" at the back of the book would have been a more useful starting point for those wishing to read more about these individuals if it had been arranged by chapter and had page numbers for the quotes.

The illustrations, which are liberally scattered throughout and take up almost a third of the book, are predominantly exquisite colour reproductions from the 18th and 19th centuries. They are well chosen to illustrate the birds or activities written about in each chapter. However, I would have preferred the captions to be with the illustrations, rather than in a list at the back of the book. Also at the back of the book are separate indices for birds and people.

Ultimately this is a book about people passionately pursuing their hobby of interacting with birds in many and varied ways.

CYNDI M. SMITH

Canmore, AB, Canada

Flock Together: A Love Affair with Extinct Birds

By B. J. Hollars. 2017. University of Nebraska Press. 244 pages, 37.50 CAD, Cloth.

"What must it feel like to be the last person to ever see a species?" (p. 116)

Goosebumps rose across my skin as I read this line, and my imagination immediately ran away. Throughout this entire book, that thought kept crossing my mind. What would it have been like to see the last Ivory-billed Woodpecker (*Campephilus principalis*), or to visit Martha, the Passenger Pigeon (*Ectopistes migratorius*), at the Cincinnati Zoo, knowing this was the last of her kind? *Flock Together* is a tragic love story between humans and extinct birds, the quest to find them again, and the hope that history will stop repeating itself.

I was surprised to learn that the author was neither an ornithologist nor a birder. Normally, I would be slightly sceptical of a book about birds not written by someone who studies them or identifies himself/herself as a birder; however, I found that this characteristic added to the charm of the book. While the book doesn't seem to have a particular audience in mind, it would likely engage those who may be intimidated reading a non-fiction book about birds because little jargon was used throughout. Whether you have an interest in conservation, are a beginning birder, or are a seasoned ornithologist, you will be able to identify with the author's year-long journey. The book documented the author's pursuit of knowledge and his growth as he explored and learned more about these extinct species. It reminded me of what attracted me to the environmental field in the first place, that feeling of hope, wonder, and longing to preserve our natural world.

Flock Together is divided into four sections: glimpsing, spotting, seeing, and knowing. These sections orga-

nize Hollars's journey into learning more about extinct species and the people who observed and studied them, as well as his observations on species today. Throughout, the reader is intimately acquainted with the Ivory-billed Woodpecker, to which Hollars refers as his "spark bird", the bird that began his interest in our avian friends. Though the main focus was on the Ivory-billed Woodpecker, we are also briefly introduced to the Passenger Pigeon, the Carolina Parakeet (*Conuropsis carolinensis*), and the Dusky Seaside Sparrow (*Ammodramus maritimus nigrescens*).

While the title suggests a "love affair with extinct birds", we also see Hollars's "love affair" and admiration for those who sought to save the species. We become acquainted with several people including: naturalist Francis Zirrer, conservationist and Passenger Pigeon expert Bill Shorger, painter Don Eckelberry, modern birder Steve Betchkal, and museum curators such as Paula Holahan.

While I was surprised that this book tends to focus more on the people striving to save species from extinction than the species themselves, it was a wonderful read. Hollars did a thorough job researching and trying to understand the lives and perspectives of these individuals in his writing, he projects a modesty that many of us can relate to at a time when we were (or are) fledglings in a field of study. His writing style is also one that is very easy to connect with, free of jargon yet effectively communicating the history of endangered species and the urgency facing many species still alive today. Hollars manages to sound the alarm on human-induced extinction without being overly preachy.

Toward the end of the book, Hollars paves the way for future thought and discussion regarding our role in extinction. While the book did focus on extinct birds, it brings into question the status of all species still present today and how human desires often shape their futures. However, Hollars noted it best when he said, "What we often fail to realize... is how their futures shape our own" (p. 176). This circular narrative is what I enjoyed most about this book. Many of the insights,

from both Hollars and others in his book, make us value not only what we could travel to see, but also what is in our own neighbourhood. It reminds us that while we need to strive and protect species that are at risk, we must also place value on keeping common species common.

TIANNA BURKE

Nobel, ON, Canada

Fireflies, Glow-worms, and Lightning Bugs: Identification and Natural History of the Fireflies of the Eastern and Central United States and Canada

By Lynn Frierson Faust. 2017. University of Georgia Press. 376 pages, 32.95 USD, Paper.

This book has a cool cover (a firefly courting in the dark, leaving a glow-trail), reflecting the overall cool of this book (go ahead, read the book and judge for yourself). Second impression: the front cover and opening end paper both unfold to reveal a key to flash/glow patterns and colours of more than 60 species (who knew there were that many?). Very cool.

This book is set up very much like many other family-level monographs; that is, several introductory chapters precede the species accounts. Terminating this book is not only an extensive references section (as in other monographs), but a glossary (not rare, but sadly not universal) and, uniquely in this book, The Selangor Declaration, which briefly explains the issues fireflies (and other species) face, and proposes to governments to encourage more understanding of fireflies and to take steps to protect them.

The first introductory chapter is an introduction to the genera. This is useful, but in my mind, should have ended with a key. The target audience of this book seems to be serious naturalists who may want to explore the fireflies more deeply, and to them a key to specimens would be necessary. In this chapter, we are also introduced to the railroad-worm, *Phengodes*: another glowing insect, but not a firefly. Yes, we are told what it is not, but never told what it is. (Just so you know, it is part of the glow-worm beetle family, Phengodidae, and they are closely related to the fireflies, Lampyridae.)

Further introductory chapters cover diversity, development, survival, predation and parasites, and research advice. There was also a "Frequently Asked Questions" chapter: I've never seen such a treatment outside the internet. I found it an odd collection of miscellanea and, as with similarly-named internet pages, I wonder if all these questions truly are "frequently asked", or if the information presented just didn't fit nicely anywhere else.

The "Species Accounts" are the meat of this book. They are organized by genus, well-described, and profusely illustrated. Just as I lamented the lack of a key to genera, keys to the species are notably absent. I do realize that there are species groups of uncertain compo-

sition, but a key could then justifiably end in, for example, "*Photuris versicolor* group" or "*Pyroctomena linearis* complex". That aside, all the classic sub-headings are here: appearance, range (maps would have been better than text), habitat, similar species, a synopsis of some of the key research, and other notes. The flash pattern is reproduced here, which is convenient despite the patterns being on the front pullouts. Reproducing them meant that no continuous flipping back and forth was required.

As with the great majority of insects, most fireflies do not have common names. However, Faust has included names for each species, most coined by her, a few by others. Some I can live with (e.g., Shadow Ghost, Little Gray) whereas some just seem silly, perhaps intended to catch the attention of children (e.g., Loopy 5, Mr. Mac, Low Slow Glows). I just can't imagine saying some of those names out loud in front of other adults. However, giving a creature a common name brings it an important step closer to being cared about by the general public, so I do applaud that this has been done.

It is conventional in scientific writing to write the formal species name in full (e.g., *Homo sapiens*) the first time it's used, thereafter abbreviating the genus (*H. sapiens*). A problem arises when one deals with two genera, each starting with the same letter. In this book, there are seven genera of fireflies beginning with the letter 'P' (as well as the railroad-worm, *Phengodes*). Despite this, Faust abbreviates the genera in the text, leaving the non-expert unsure of the genus.

Within the "Species Accounts" is a section, "Similar Species". Perhaps just a minor point, but when a similar species is mentioned, the reader will likely want to have a quick look, so a page reference would have been convenient.

Many personal anecdotes describe interactions with dangerous wildlife, traipsing through marshes, the discovery of a new population; all of these should intrigue the novice and bring a sense of déjà vu to those of us who engage in such pursuits. "If you think you can remember everything [that happened in the field], well you can't, and you won't" (p. 66). Truer words

were never spoken about a field biologist, one that bears repeating over and over (Randy, are you listening?).

Despite there being a glossary of over 100 terms (which is great!), words are routinely parenthetically defined (and not infrequently redefined over and over) within the text of the book, creating annoying speed bumps in one's reading. Also, the author ignores some standard anatomical terminology and uses alternates that are confusing. For example, Faust uses the phrase "lower margin" of a sternite (a ventral body plate) to mean the "posterior margin". She does this because the photos for which this term is used show a ventral aspect of the specimens with heads pointing to the top of the book, thus making the posterior margin low in the photograph. Why not just use the standards that many read-

ers know, and not introduce non-standard terminology to the new folks?

Despite my few critiques, I enjoyed the book and, more importantly, was inspired by it. I will go to my museum and find out more about our local species, their phenologies, and develop a stronger appreciation for them. Everyone who's seen fireflies aglow is pleased, comforted, or amazed with what they've seen. Who dislikes fireflies? This book will be with you outside at night, with your book light attached, while you try to identify your first flashing firefly to species.

RANDY LAUFF

Department of Biology, St. Francis Xavier University,
Antigonish, NS, Canada

OTHER

Mourning Nature: Hope at the Heart of Ecological Loss and Grief

Edited by Ashlee Cunsolo and Karen Landman. 2017. McGill-Queen's University Press. 332 pages, 37.95 CAD, Paper, 110.00 CAD, Cloth.

I went out of my usual comfort zone to review this book, feeling that it might be too intellectual for me, but wanting to extend myself a bit. The subject is grief and mourning for environmental change and I have had a share of that, so I felt somewhat qualified. Pamela Banting opines on the cover that, "while scholarly in nature, it [the book] is accessible to general readers who might be struggling with ... environmental loss, geographical displacement and activist burnout". There can't be many thinking people who don't qualify in one or more of those categories.

The material in the eleven main chapters covers a huge range of topics, from the fairly obvious (in this context) – mourning in different traditional societies (Chapter 2, Menning) and the ramifications of the decline of sparrows in the United Kingdom (Chapter 4, Whale and Ginn) – to the much less obvious: the way that extinction affects natural soundscapes (Chapter 1, Krause), the role of art in ecological grieving (Chapter 8, Barr), and podcasting environmental grief (Chapter 9, Mark and Battista). A thread that seems to hold many of the chapters together is the idea that grieving is a necessary process in the context of loss, that some sort of catharsis will help us to move on from the source of our grief. The problem with environmental grief is that it seems endless. We are besieged by bad news at every turn: coral bleaching, melting permafrost, species extinctions, particulates in the air, plastic in the ocean: the bombardment never relents. As Arundhati Roy says, in *The God of Small Things*: "...the less it mattered, the less it mattered. It was never important enough. Because Worse Things had happened... Worse Things kept happening".

Krause's chapter on natural soundscapes added another grief for me. Krause suggests that these soundscapes form the basis for human music, surely our greatest achievement and one that impinges very little on the environment. If the gradual fading of nature's sounds – the songs of birds, whales, and frogs, everywhere much diminished, the wind in the trees, the bubbling of free streams, already everywhere channeled and impounded, and the lapping and crashing of the ocean waves, soon to be tamed by wave-power installations – impinges on our ability to create and sustain music, the loss for all of us will be catastrophic.

A much more relevant subject is the role of public grieving via ceremonies, songs, monuments, blogs, and art installations in helping to raise awareness and hence change behaviour towards an ecologically sustainable lifestyle. Most of the chapters touch on this topic, and the authors describe many ingenious ways in which consciousness is being raised, but it is hard not to recognise that after several decades of increasingly shrill warnings, nothing much seems to change.

Who will enjoy reading this book, apart from the obvious audience of similarly interested academics? Actually, enjoy is not the right word here. It is impossible not to be touched by sadness when reading many of the chapters. Perhaps the act of reading the book can become part of our grieving process? I think it will appeal to those who appreciate the sweet sorrow of melancholia, and have some useful and perhaps counterintuitive lessons for those involved, professionally or by avocation, in conservation messaging. However, don't pick it up for a light read. Both in terms of content and of style, this is very heavy going.

TONY GASTON

Ottawa, ON, Canada

This River Beneath the Sky: A Year on the Platte

By Doreen Pfost. 2017. University of Nebraska Press. 198 pages, 18.95 USD, Paper.

A few years ago, I had the pleasure of spending a couple of days in late March watching Sandhill Cranes (*Antigone canadensis*) along the Platte River near Kearney, Nebraska. I can still conjure up the sight and sound of tens of thousands of cranes flying in to roost for the night on sandbars in the river and leaving again at sunrise. It was deafening and exhilarating. In *This River Beneath the Sky*, Doreen Pfost's lyrical prose brings this grand spring spectacle alive for the reader, but goes beyond the cranes to describe a river that has undergone tremendous changes since Europeans arrived in the area and, more recently, limited restoration. This book is an ode to falling in love with a place where Pfost had despaired of finding magic to hold her (she admits to having hated almost everything about the area when she first moved there).

This River Beneath the Sky is a collection of 12 chapters (essays, really) roughly corresponding to the calendar year, starting with welcoming the cranes back in late March (Chapter 1: "Swept up in a wind-borne river"). In Chapter 2 ("Regarding the aftermath") Pfost discusses the impact of diverting over half of the Platte's flow for agriculture and power generation. This means not just less water overall, but also narrower, incised channels and fewer sandbars; no seasonal flooding of riverside meadows that the cranes depend on for feeding; changes in the timing of the flow; and more riparian forest and invasive weeds because spring floods no longer scour the seedlings away. Pfost goes on to describe these changes in other chapters, through careful observations during rambles throughout the seasons.

While historical anecdotes are sprinkled throughout, Pfost highlights the first impressions of emigrants on the Oregon and Mormon trails in Chapter 3 ("Trails and consequences"), and those of the early homesteaders in Chapter 4 ("Rooted in sand"). Unfortunately, the Pawnee tribe of Plains Indians is only mentioned briefly, in their relationship to bison: when the bison were extirpated, the Pawnee left, too. In the 25 years between 1841 and 1866, it is estimated that some 350 000 emigrants passed westward along the Platte River valley. The trails followed the meandering river through a sea of grass, a "featureless" landscape that drove many early travellers to despair. Within a decade some of the emigrants stopped to homestead in the area and all that grass has now been replaced by irrigated corn fields, towns, cities, and highways.

Pfost returns to the river itself in Chapter 5 ("Of legendary worth"), when she follows the North and South Platte rivers to their headwaters in Wyoming and Colorado. (The simple sketch map included in the book is useful, but a few more place names on it would have been helpful; for instance, Pfost frequently refers to The Big Bend, which I assume is just upstream of where the Platte joins the Missouri River, but it isn't labelled.) Along the way she encounters the series of dams and big irrigation projects that fundamentally altered the

river along its entire length. There is often "more river on the fields than in channel" (p. 81). Of course, the impacts from climate change are uncertain, but include less snow in the Rocky Mountains to feed the river and higher temperatures, which will increase evaporation from the fields thus requiring more irrigation water. These human needs will compete more and more with the needs of aquatic systems and wildlife.

Efforts at restoring the river's character, its flow and seasonality, are highlighted in Chapter 6 ("River walkers") and Chapter 7 ("Flickering light on the flyway"). Restoration efforts include removing trees, excavating sloughs, reshaping islands into sandbars, and changing the flow so that water runs through braided channels. Much of the restoration work started at the National Audubon Society's Lillian Annette Rowe Sanctuary, where Pfost volunteers. While in an airplane conducting Whooping Crane (*Grus americana*) surveys, Pfost notices the long, indented streaks where the ground dips in old river channels and writes that "No matter how much water humans take from the river or how much we forget about the Platte's old ways, the land remembers", and she imagines "spreading a great sheet of paper over the fields and rubbing them with chalk to preserve this channel's epitaph", like rubbings made of ancient art (pp. 113–114). In a short recounting of Whooping Crane recovery, Pfost likens the barely two dozen cranes that were the entire population in the 1940s to two cartons of eggs on the kitchen counter, "one sharp elbow away from destruction" (p. 105).

The next four chapters ("Outside home", "This living planet", "Teaching ourselves to see", and "Wonders close to home") are more introspective, perhaps befitting the time of year, late November through February. She takes short walks in nasty weather ... "sometimes even a short walk is enough to reset the mind's gyre" (p. 154). She joins other volunteers to count wintering Bald Eagles (*Haliaeetus leucocephalus*) "when you share what you see with other people, you begin to notice more yourself" (p. 150), and writing observations down is also a way to observe more.

Finally, in Chapter 12 ("Swept up, still and again"), the cranes return. With them come tens of thousands of visitors, wanting to experience one of the last great migrations on the continent. When naturalists and biologists were fighting grand water diversion schemes in the 1960s and 1970s there was little notice of the changes happening to the Platte, but now the influx of visitors has drawn the attention of local communities, businesses, and chambers of commerce, "so the Platte River may benefit from the same principle that protects large flocks of vigilant migrating birds: anything is safer when many eyes are watching" (p. 15).

Ultimately, this is a book of hope, encouraging the reader to "travel not farther but deeper" (p. 170).

CYNDI M. SMITH

Canmore, AB, Canada

The Book that Changed America. How Darwin's Theory of Evolution Ignited a Nation

By Randall Fuller. 2017. Viking. 304 pages, 27.00 USD, Cloth.

This is a stimulating history set in the 1860s but still germane today. It centres on the American (USA) reception of Darwin's *Origin of Species*, focussing on one copy of the book and on a small group of New England intellectuals and their enthusiastic embrace of Darwin's careful logic and reliance on empirical evidence (aka facts), a marked contrast to the prevailing transcendental thinking of the time. In the preface, Fuller states, "This book is a biography of the single most important idea of the nineteenth century. It is also an account of issues and concerns that are still with us, including racism ... and the enduring conflict between science and religion". My own biases would claim the theory of natural selection the most important idea ever and that this book reveals other enduring social ills than just racism.

As someone who has read and thought a great deal about evolution and Darwin for several decades, I have found books on these topics often struggle for novelty of ideas. This book achieved novelty for me in that I had never thought of the *Origin* as a weapon in the war against slavery and virulent racism, despite being aware of Darwin's strong abolitionist sentiments (see *Darwin's Sacred Cause*, by Adrian Desmond and James Moore, 2009, Penguin Books). Indeed, I have always thought that the *Origin* could be used to support slavery given the alternate title "The Preservation of Favoured Races in the Struggle for Life". And Fuller allows that such was the case in the USA, but that the real impact was to "disprove" arguments that African slaves were not merely inferior to "whites" but were a separate and inferior species.

By 1859, America was heading for a conflict over slavery with northerners generally becoming more opposed to slavery whereas in the south slavery was becoming more entrenched. Into this developing cauldron Darwin sent the first copy of his book to a Harvard botanist and good friend Asa Gray. Gray championed the book and the theory of natural selection and the book was passed among four other men, the abolitionist Franklin Sanborn, the philosopher Branson Alcott, the naturalist Henry David Thoreau, and the child welfare reformer Charles Loring Brace. In addition, three influential writers were early readers, Louisa May Alcott, Ralph Waldo Emerson, and Frederick Douglass. The responses and activities of these leading abolitionists are a significant part of the book. Fuller makes the claim that the *Origin* was a bombshell that "blasted American intellectual life to pieces" and led to its reconstitution. I am not so sure he makes this case, but he has put together a wonderful portrait of the religious, social, and scientific battles as America headed into the disastrous civil war, whose tensions still, of course, reverberate today.

Focussed as it is on about three years (1859–1862) and this handful of intellectuals, the book shows splendidly how a single powerful idea can infiltrate and transform every part of a culture and, to some extent in

this case, replace its myths with new ones. In this case, the idea was Darwin's brilliant presentation of his theory and the culture was that of pre-civil war America steeped in its beliefs that all species were separately created by a divine being, and that humans were being guided to perfection by this same creator. This culture was being ripped apart by the issue of slavery.

Today, America is writhing in crises engendered by the growing wealth gap and by the continuing discord of rampant sexism and racism, even in our most cherished institutions. But these current battles pale compared to the seething struggle over slavery reflected in the dramatic contrast between the language of the American constitution and the reality of a country built on the brutal institution of slavery. (I won't digress into the systematic extermination of much of the indigenous population nor of the comparatively minor, terrible treatment of various immigrant minorities.) As one reads this historical account, one can't help but drift into thinking about the current chaos in America, or "western" culture for that matter, and wonder if anything has really changed or "progressed" in the century and a half since the publication of the *Origin*.

The central theme of Fuller's account is that the early reception of the *Origin* by the abolitionist forces was enthusiastic, taking it as scientific support for their contention that all "races" were derived from a common origin and were not separate creations, as claimed by many biblical scholars, Christians, and plantation owners. To many abolitionists, the arguments and data in the *Origin* showed that the assessment that black slaves were a lesser, subhuman species was not correct. Fuller expands on this core by recounting the discussion by Gray and the gang of five on the merits of Darwin's theory. Although Fuller includes *Darwin's Sacred Cause* in his bibliography, as far as I can tell he does not mention or refer to it in his text. This is unfortunate because this book makes the argument that Darwin to some extent structured his arguments to reflect his view that slavery and its racist claims were an abomination. I wonder if that bias made the *Origin* more palatable to American abolitionists.

A second theme of the book is that these intellectuals were deeply adherent to the study of nature as a means of revealing the "mind" of the creator and as a guide to how this creator had put humans on a path to "perfection". They pursued these goals by positing "first causes" (i.e., spiritual causes), and as a more mundane matter investigated secondary causes such as physical laws derived from first causes. People often rejected Darwin because he did not address first causes, but instead adhered to clearly empirical, material explanations that could be tested. This approach was attractive to the abolitionists, and they initially overlooked the conflict with their "spiritual" views.

A third theme is that an enthusiastic response to the *Origin* did not extend to all or even most who read it. Many scientists/biologists fulminated against Darwin,

perhaps none more famously than the most notorious scientist of the day, Louis Agassiz, like Gray, a Harvard professor. Agassiz campaigned against Darwin and evolution and whole heartedly defended the separate creation of species. He had a profound distaste for African-Americans. He and Asa Gray battled in public, and Agassiz travelled extensively seeking support for his views that blacks were inferior to whites in many ways, though he was against slavery. After Agassiz arrived in America to take his chair in Harvard, his scientific research declined in quality as he became more of a public speaker, making claims such as the study of Nature leading to the "free conception of the Almighty Intellect". Amen!

As the debate over Darwin's ideas hardened, it began to occur to many of his supporters that there was a problem. Gray and others in their initial fervour managed to ignore the contradiction between their religious views and those of the culture of transcendentalism, versus the meat of Darwin's main message. Natural selection is a brutal, totally materialistic explanation, not requiring a divine designer, or any other "spiritual" force. This lack of spirit and the apparently accidental nature of human existence, one no different than that of any of the lesser species, drove even the most committed Darwinists to start bending the theory to fit what they had believed before. Fuller even inserts a smidgen of the dispute between Darwin and Alfred Russell Wallace over Darwin's dismay at Wallace's embracing "spiritualism" and his refusal to accept that humans were not special creations of a great designer.

This sad state of affairs leads to one of the most interesting parts of the book for me. In reading the comments and writings of the key intellectuals included by Fuller, two things seemed apparent. First, not much appears to have changed since 1860. Yes, we now have much greater support for the theory of evolution by natural selection from all areas of science and, yes, we have greatly expanded the culture of Western liberalism regarding civil rights, universal suffrage, equality of race, gender, ethnicity, sexual preference, etc., but creationism, racism, sexism, misogyny, homophobia, and more continue to exist just under the surface, or even above it, in a significant proportion of citizens. Some of these views are less brutal and visible today. Slavery, for example, is not a cornerstone of modern society, but it is not gone nor is it terribly unlikely that it could arise again.

Perhaps the key conundrum of the 1860s was whether all humans descended from a common ancestor like Adam and Eve, or were they separately created and, if so, did this contradict or support biblical "evidence"? This argument seems comical today, doesn't it? Second, the battle between science and religion has barely dimmed. Even though much organized religion has declined in America, the beliefs in gods, spirit, miracles, souls, and the search for "meaning" beyond the cold blade of science continue without abatement. Fuller

notes that in his defense of the *Origin*, Asa Gray "suggested" that readers of Darwin had to be open to the possibility that everything they had taken for granted was in fact wrong. That is a difficult possibility to be open to. Fuller states that the tone of Darwin's book, so reserved, so reasonable, cloaked insights that were explosive and unsettling. Even though many of the early supporters of the theory saw this from the start, it took time for those insights to become problematic. Darwin reduced the importance of humans much as Copernicus and Galileo before him and muddled "our" relationship with God. These threats caused unease and still do.

I was surprised by Fuller's assessment of the effect of the *Origin* on Henry David Thoreau. Fuller argues that Thoreau read the *Origin* most closely and was changed by it substantially. "The simple fact that animals must consume other animals to survive" upset Thoreau, yet he saw that Darwin provided an explanation for this "murderous subtext". Competition and struggle influenced the whole economy of nature, created new forms, and was, to use Fuller's phrase, "the cost of doing business". Thoreau made a huge shift in thinking, from seeing Nature as a creation meant to serve man's needs to a view that Nature's organization was accidental, a product of random and haphazard occurrences. There was no design, no plan, and at the individual level chance prevailed. This perspective could hardly be more different than the prevailing "Christian" view of Nature. Thoreau eventually came to revel in the prodigious capacity of life to adapt and multiply. At this point (p. 144), Fuller inserts the inspiring final paragraph of the *Origin*, "It is interesting to contemplate...". Eventually, Thoreau, who collected myriads of data on his daily walks, realized he needed to be organized, like Darwin, and he invented a spreadsheet and meticulously on winter days filled it with his unorganized field notes. He became a scientist searching for a grand unifying pattern of life.

Ultimately, Fuller concludes that Darwin's methodical use of material evidence and hypothesis testing became central to biology, except for those many who could not see the evolution of complex adaptations without the guiding hand of Providence. Loren Eiseley, intellectual heir to Thoreau, summarized the Darwinian view nicely: "We have played roles as amphibians, then reptiles far longer than we have been men. Our identity is a dream" (p. 245). Humans, opined Thoreau, were not products of a divine miracle maker, but a product of lineal descent and geographical distribution. Yet like racism, misogyny, and spiritualism, the divine planner still reigns in the minds of many today.

In summary: I have omitted mention of at least a third of this book. It is filled with stimulating discussion of biology, philosophy, racial issues, and more. It is a great read, don't pass it up.

RON BROOKS

Guelph, ON, Canada

The Arctic Guide: Wildlife of the Far North

By Sharon Chester. 2016. Princeton University Press. 544 pages, 27.95 USD, 22.95 GBP, Paper.

The Arctic is often seen as a vast wilderness, or even a frozen wasteland, that could only support a small number of living things, such as Polar Bears (*Ursus maritimus*) and Reindeer (*Rangifer tarandus*). Yet in *The Arctic Guide*, Sharon Chester gives a wonderful overview of the diversity of life in the Arctic and truly demonstrates that the Arctic has a plethora of incredible organisms living there. *The Arctic Guide* is formatted like most standard field guides, with hundreds of pages of species descriptions, distribution maps, and colour plates for identification. However, unlike most field guides, *The Arctic Guide* covers a very wide range of taxa, including plants, some insects, and all vertebrate fauna. And even with this large volume of fauna and flora, the guide is still relatively compact and can easily fit in a small backpack with other essential field gear. Not only does *The Arctic Guide* cover a wide range of taxa, but it also covers a wide geographic range, including all eight countries that lie within the Arctic Circle. Overall, this guide is an excellent overview of Arctic biodiversity for new Arctic travellers interested in biodiversity.

Author Sharon Chester is a wildlife photographer, illustrator, and naturalist who has written several other books about wildlife and natural history, including *A Wildlife Guide to Chile* (2008, Princeton University Press) and *Antarctic Birds and Seals* (1993, Wandering Albatross). She has spent a lifetime learning about the natural world and has thoroughly researched the wildlife presented in this guide. She even provides common names in multiple languages, including local indigenous languages.

An important criticism of this book is that it covers far too many species to go into proper detail for species identification. The small amount of text and single image for most species are not sufficient to differentiate between similar species. This is especially apparent for small mammals, such as shrews and voles. Experienced naturalists should use an appropriate taxa-specific guide for more details about species identification. Similarly, not all scientific names are correct. The author states that scientific names were up-to-date at the time of writing, but may have become out of date during the publication process. Yet some names are more than 10 years out of date at the time of publication. For example, the Wood Frog is called *Rana sylvatica* in the text, yet it has been known as *Lithobates sylvaticus* since 2006 (Crother 2012). Readers interested in up-to-date scientific names should look in taxa-specific reference materials.

The author introduces the Arctic with an overview of different definitions of where the Arctic begins (such as the Arctic Circle [66°34'N] and the tree line), as well

as common physical features and zones within the Arctic. This is a very useful section that can help a first-time visitor to the Arctic understand the region. Despite this very clear introduction to what the Arctic is, the author doesn't seem to stick to any given definition when including different species in this book. Species from the boreal and taiga ecozones are included in the guide if they live past the Arctic Circle, and are discussed as much as species that are found only in the Arctic. Perhaps less emphasis should be placed on these sub-Arctic species. Similarly, for species with more southerly distributions, information is presented that is only specific to populations living in the southern extent of their range. For a book focussed on species of the Arctic, the information presented for these species should be specific to populations that live in the Arctic.

The author made a small attempt to include invertebrates in this guide with the section on flies, bees, and butterflies. However, most of this section focuses on butterflies: 3.5 pages were devoted to flies and bees and 20.5 pages to butterflies. Either the chapter could have just focussed on butterflies or more information should have been presented on the other insects. Moreover, this section represents only a small fraction of invertebrate taxa in the Arctic, so justification is needed for the exclusion of other invertebrate taxa. A similar criticism can be made for the section on flora. It is introduced as a section on plants, but then spends 10 pages discussing cyanobacteria, mushrooms, and lichens. This section should therefore be titled a bit more broadly.

Despite these criticisms, *The Arctic Guide* is an excellent introduction for those interested in a wide range of taxa, so long as they are not looking for detailed species accounts or identification information. Then again, a guide covering this same wide range of taxa across the entire Arctic that also included detailed identification features and keys would be at least twice the size, which would remove its current utility as a portable field guide. I would recommend this guide to any naturalists traveling to the Arctic for the first time as a broad overview of the biodiversity that they might encounter.

Literature Cited

Crother, B. I. 2012. Scientific and Standard English Names of Amphibians and Reptiles of North America North of Mexico, with Comments Regarding Confidence in our Understanding. Seventh edition. Society for the Study of Amphibians and Reptiles Herpetological Circular 39.

WILLIAM D. HALLIDAY

Wildlife Conservation Society Canada, Whitehorse, YT, and
Department of Biology, University of Victoria, Victoria,
BC, Canada

Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming

Edited by Paul Hawken. 2016. Penguin Books. 256 pages, 22.00 USD, Paper.

Climate change is a complex, multi-scale issue that needs to be discussed in the context of its social, ethical, environmental, economic and political drivers, impacts, and solutions. *Drawdown* is part of an emerging conversation that clearly identifies viable solutions while also asking difficult questions about finding our moral compass: What future do we want for humanity? How can wealth be shared more equitably? and How do we create a livable planet for humans and all biodiversity?

The book is a compilation of credible, science-based solutions intended to halt and, more importantly, reverse human caused greenhouse gas (GHG) emissions. Hence the name “Drawdown”, something they say we need to embrace if we are to successfully prevent catastrophic impacts of climate change. The book avoids jargon and acronyms, providing a plain language, straightforward discussion of 80 possible solutions under the headings of Energy, Food, Women and Girls, Buildings and Cities, Land Use, Transport, and Materials. There are also 20 Coming Attractions recognizing this is a field of emerging solutions, some of which might work, others not. Nevertheless, there are serious efforts looking for solutions!

Project Drawdown’s long list of distinguished “Fellows” and “Advisors” (short biographies provided) have selected and ranked 80 viable climate solutions based on the number of gigatons of carbon dioxide they can reduce or remove in 30 years (2020 to 2050). You will be surprised at the top three solutions: 1. Refrigerant Management (CFCs and HCFCs are 1000 to 9000 times more potent than carbon dioxide as drivers of climate change, and air conditioning and refrigeration use is on the rise globally); 2. Wind Turbines – Onshore (cited as now being the lowest cost source of new electrical capacity); and 3. Reduced Food Waste (efficiency reduces emissions associated with agriculture and food production and transportation, and increases carbon storage by preventing unnecessary deforestation).

The numbers presented are said to be conservative estimates, recognizing the modelled scenarios could do even better with potential declining costs (e.g., solar

panels), new technologies, and our willingness to invest. For most solutions the “net cost” of implementation (purchase, install, operate) and “net savings” (based on the cost of the solution compared to following a “business as usual” approach) over the 30 years of analysis are also presented. Cost effectiveness is highly variable and it is not linked to amount of GHG reduction: for solar farms there is a negative net cost of \$80.6 billion (i.e., solar farms generate revenue as electricity is sold) and net savings of \$5 023.8 billion over conventional electricity generation; for electric vehicles there is a net cost of \$14 148.0 billion (people need to manufacture, purchase, and maintain cars) and net savings of \$9 726.4 billion (i.e., it’s cheaper to stick with conventional internal combustion engine cars). So there are both obvious smart choices (solar farms) and moral choices (consumer driven purchase of electric cars). (See <http://www.drawdown.org> for the data, analysis, and references associated with each solution.)

Drawdown includes an array of topics presented as concise (2–4 page) discussions that will appeal to a wide audience. You can thumb through the book choosing interesting pieces or focus on specific areas. Did you know peatlands cover 3% of the earth’s land surface and are second only to oceans in the amount of carbon they store! *Drawdown* also includes some remarkable essays, such as an excerpt from Pope Francis’ encyclical letter “On Care for Our Common Home” and an essay on food by Michael Pollan, author of *The Omnivore’s Dilemma*.

Drawdown is enlightening, it’s not afraid to criticize itself, exposing data that are weak or probabilities of uptake might be low, and it gives climate change solutions the human dimension needed for us all to embrace the new ethos required to face the new climate world we have created for ourselves. *Drawdown* is highly recommended for those looking for hope that we will be able to face the challenges of the 21st century.

BRENT TIGLER

Liana Environmental Consulting Ltd., Fergus, ON, Canada

The Sustainability Dilemma: Essays on British Columbia Forest and Environmental History

By Robert Griffin and Richard A. Rajala. 2017. Royal BC Museum. 448 pages, 34.95 CAD, Paper.

Part of the Royal BC Museum (RBCM) catalogue, the meticulously researched *Sustainability Dilemma* examines British Columbia’s (BC’s) questionable implementation of post Second World War sustained-yield forestry and multiple-use resource policies. Despite the book’s title, the authors do not dwell on sustainability theories; rather, they maintain their focus on negotia-

tions and conflict inherent in the BC Forest Service’s execution of “sustained yield” in a system of industrial forestry. In the immediate post-war era, the forest was considered a farm growing a perpetual crop of trees from which to derive revenue. The best way to manage such imagined farms thus became a pressing question, as strategies pursued would either help or harm a range

of social and environmental interests. The book begins with Griffin's three-chapter essay that investigates the emergence of sustained yield policies and then those same policies in action. In the second part, Rajala pens two case studies on the conflicts which arose between those attempting to maximize forests and fish. Collectively, the essays discover and analyze rich new archival sources and so extend BC's forest history literature.

Both contributing authors have longstanding relationships with the museum. Both authors also have a tremendous depth of knowledge regarding BC's forest history. Dr. Robert Griffin served as the RBCM history curator for more than 30 years and has written many articles on the forest and mining industries. His most recent output includes *Stewards of the People's Forests: A Short History of the British Columbia Forest Service* (with fellow curator Lorne Hammond; 2014, RBCM). Dr. Richard Rajala is an associate professor of History at the University of Victoria, and a Research Associate at the RBCM. Prior to the volume under review, Rajala's previous book was another fine museum publication, 2006's *Up-Coast: Forests and Industry on British Columbia's North Coast, 1870–2005* (2006, RBCM).

Griffin's shorter three-chapter essay begins the book. Chapter 1, starts in the late 1940s and ends in the late 1970s. Through the period a sustained-yield policy was implemented and thought to be functioning somewhat satisfactorily, despite the forest bureaucracy's inability to shift policies and procedures fast enough to match community expectations. Chapter 2 examines industry responses to the overwhelming task of implementing sustained-yield policies, as represented by an in-depth study of the central-interior company Western Plywood (later known as Weldwood and then West Fraser). This eye-opening material portrays simultaneous cooperation and competition between smaller operators as they sought to manage the provincial timber sales process themselves, via collusion, rather than the Forest Service's bidding practice. Collusion occurred within very specific limits, duplicating similar European industry cartels of the 1890s. Griffin places blame for timber shortages on operator greed and government policy, not Forest Service incompetence as has sometimes been suggested in other unnamed studies. Finally, Chapter 3 explores the major policy changes that sought to maximize use of the resource by minimizing sawmill waste. What waste could not be avoided was redirected as an input for pulp and paper mills.

Griffin sticks very close to the archives, with minimal wider contextualization; almost all of the references are to primary sources with very few to the allied supporting secondary literature. Pace through time was fairly quick, which meant a fast parade-past of individuals, companies, and locations. This would tend to make it a narrative for insiders, rather than the uninitiated. So structured, the text demands some degree of existing knowledge of both logging and forestry; for

example, the purpose of planer mills is assumed rather than explained (p. 10). At the outset, the narrative is related from the Forest Service's point of view, rather than politicians, industry, or labour; this changes in the later chapters, which are told from the viewpoint of a particular company. There are many interesting images, though they are left to speak for themselves and were not contextualized as well as they might have been.

The much larger portion of the book is devoted to Rajala's two themed case studies. Both explore the constitutionally-rooted conflicts between provincial forest managers' aspirations to maximize the harvest of wood, and the competing aims of federal fisheries managers and proto-environmentalists who sought to safeguard the spawning habitat of salmon, prized by the commercial fishery, and trout, highly valued by the recreational rod and gun clubs. Chapter 4 provides a very close reading of the Stellako River controversy as it unfolded between 1950 and 1970. In short, this is a local story with national significance, one of "the grandest and most destructive traditions of North American lumbering—the river drive" (p. 121). Conservation discourse of the time suggested that when science was combined with the regulatory power of the State to pursue sustainable practices, conflicts could be resolved via the philosophy of multiple-use. Rajala does a good job of reminding the reader that such an outlook did not imply an equality of uses. The BC forest industry's pre-eminence as a generator of revenues and jobs meant that its requirements more often than not ranked first in the hierarchy. The result being that log drives were allowed on the Stellako, and logs gouged gravel spawning beds and shed tree bark that covered what fish habitat remained. Writer and conservationist Roderick Haig-Brown and fishing-resort owner and anti-log-drive crusader Doug Kelly emerge as heroes of this story, highlighting the environmental leadership provided by sportsmen during the 1960s.

The book's fifth and final chapter turns from the interior to the north coast. One theme that unites Rajala's two cases is the role of science and, more importantly, scientific uncertainty, exploited by capital and the province, to urge inaction with regards to protecting fish spawning habitat in the light of competing resource uses. Here, Riley Creek on Haida Gwaii is the site of higher elevation logging that some feared would result in devastating landslides, slope failures that indeed did occur depositing tonnes of material in the watercourse. This is another story of power and control, with losers such as federal fisheries officer Jim Hart and Haida fisherman Charlie Bellis, and short-term winners like BC Forests Minister Tom Waterland and QC Timber. Rajala insightfully observes that no one won in the end, because those with power wielded it in ways that led to their own ultimate embarrassment (p. 335). Those who thought they had won by successfully advocating for logging practices with unknown risks ultimately assured their loss in subsequent Haida Gwaii land use

conflicts. Multiple-use forestry became increasingly discredited, along with the sustained-yield concept, legitimizing a zoning concept of conflict resolution, parks, and a postponement of “meeting the full range of human needs in truly sustainable ways” (p. 335).

Rajala provides a great quantity of fine-grained detail, having scoured every available source and included it in the narrative and notes. The job of deciding what was of greater and lesser importance is left to the reader, a strategy that will limit the potential audience for this important scholarship. For both Chapters 4 and 5, synthesis and contextualization are saved for concluding sections, important larger-scale insights that may have been more profitably shared, or at least alluded to, in the introduction of both pieces, or invoked throughout in a more condensed telling.

In sum, this is an important book by subject matter experts that goes a great distance to understanding BC resource conflicts from the latter half of the 20th cen-

tury. The essays demand a lot of the reader and are far more specific than the general title would suggest. The layperson might be attracted to the topic but these essays will be most welcome by those already well-familiar with the details of British Columbia's forest industry. The neophyte might more profitably begin with political scientist Jeremy Wilson's 1998 *Talk and Log* (UBC Press), historian Gordon Hak's 2006 *Capital and Labour in the British Columbia Forest Industry* (UBC Press), or even some of Rajala's own previous books. For those more familiar with the field, *The Sustainability Dilemma* charts new archival ground and builds a strong foundation for further work in late 20th century human-environment relations. Perhaps its greatest contribution is in pointing a path forward to understanding the origins of the modern BC environmental movement.

DAVID BROWNSTEIN

Klahanie Research Ltd., Vancouver, BC, Canada

NEW TITLES

Prepared by Barry Cottam

Please note: Only books marked † Available for review or * Assigned have been received from publishers. All other titles are listed as books of potential interest to subscribers. Please send notice of new books – or copies for review – to the Book Review Editor.

†Available for review *Assigned

Currency Codes – CAD Canadian Dollars, USD US Dollars, EUR Euros, AUD Australian Dollars, GBP British Pound.

BOTANY

***Plant Ecology: Origins, Processes, Consequences. Second Edition.** By Paul A. Keddy. 2017. Cambridge University Press. 624 pages, 74.95 CAD, Cloth, 52.00 USD, E-book.

Invasive Plant Species of the World: A Reference Guide to Environmental Weeds. Second Edition. By Ewald Weber. 2017. CABI Publishing. 596 pages, 320.00 USD, 195.00 GBP, Cloth.

Drosera of the World, Volume 2: Oceania, Asia, Europe, North America. By Allen Lowrie, Alastair S. Robinson, Richard Nunn, Barry Rice, Greg Bourke, Robert Gibson, Stewart McPherson, and Andreas Fleischmann. 2017. Redfern Natural History. 554 pages and 665 colour photographs, 33.24 GBP, Cloth.

Plant Conservation Science and Practice: The Role of Botanic Gardens. Edited by Stephen Blackmore and Sara Oldfield. Foreword by Sir Ghillelan T. Prance. 2017. Cambridge University Press. 253 pages, 114.95 CAD, Cloth, 51.95 CAD, Paper, 36.00 USD, E-book.

Plant Families: A Guide for Gardeners and Botanists. By Ross Bayton and Simon Maughan. 2017. University of Chicago Press. 224 pages and 300 colour plates, 25.00 USD, Cloth. For sale in North America only.

Nature's Fabric: Leaves in Science and Culture. By David Lee. 2017. University of Chicago Press. 512 pages and 514 colour plates, 35.00 USD, Cloth, 21.00 USD, E-book.

Phylogeny and Evolution of the Angiosperms. Revised and Updated Edition. By Douglas Soltis, Pamela Soltis, Peter Endress, Mark Chase, Steven Manchester, Walter Judd, Lucas Majure, and Evgeny Mavrodiev. 2017. University of Chicago Press. 560 pages, 80.00 USD, Cloth or E-book.

ENTOMOLOGY

***The Secret Life of Flies.** By Erica McAlister. 2017. Firefly Books. 248 pages, 29.95 CAD, Cloth.

The Book of Caterpillars: A Life-Size Guide to Six Hundred Species from around the World. Edited

by David G. James. 2017. University of Chicago Press. 656 pages and 2400 colour plates, 55.00 USD, Cloth, 33.00 USD, E-book.

Spiders of North America: An Identification Manual. Second Edition. Edited by Darrell Ubick, Pierre Paquin, Paula E. Cushing, and Vince Roth. Illustrations by Nadine Dupérré. 2017. American Arachnological Society. 425 pages and 1400+ black and white line drawings, 95.00 USD (50.00 USD to AAS members), Spiralbound.

Ant-Plant Interactions: Impacts of Humans on Terrestrial Ecosystems. Edited by Paulo S. Oliveira and Suzanne Koptur. 2017. Cambridge University Press. 452 pages, 97.95 USD, Cloth, 68.00 USD, E-book.

Victory Gardens for Bees: A DIY Guide to Saving the Bees. By Lori Weidenhammer. 2016. Douglas & McIntyre. 240 pages, 22.95 CAD, Paper.

Bee Quest. By David Goulson. 2017. Jonathan Cape. 272 pages, 16.99 GBP, Cloth.

***Insects: Their Natural History and Diversity: With a Photographic Guide to Insects of Eastern North America. Second Edition, Revised and Updated.** By Stephen A. Marshall. 2017. Firefly Books. 736 pages and 4000 colour photographs, 95.00 CAD, Cloth.

Pheromone Communication in Moths: Evolution, Behavior, and Application. Edited by Jeremy D. Allison and Ring T. Carde. 2016. University of California Press. 416 pages, 75.00 USD, 62.95 GBP, Cloth, 75.00 USD, E-book.

ZOOLOGY

***The Australian Bird Guide.** By Peter Menkhorst, Danny Rogers, Rohan Clarke, Jeff Davies, Peter Marsack, and Kim Franklin. 2017. Princeton University Press and CSIRO Publishing. 560 pages, 39.95 USD, Paper.

The Peregrine Returns: The Art and Architecture of an Urban Raptor Recovery. By Mary Hennen with Peggy Macnamara. Illustrations by Peggy Macnamara and photographs by Stephanie Ware. 2017. University of Chicago Press. 208 pages and 159 colour plates, 25.00 USD, Cloth, 18.00 USD, E-book.

The Seabird's Cry: The Lives and Loves of Puffins, Gannets and Other Ocean Voyagers. By Adam Nicolson. Illustrations by Kate Boxer. 2017. William Collins (Harper Collins imprint). 228 pages, 34.99 CAD, Paper.

Owls: A Guide to Every Species. By Marianne Taylor. 2017. Harper Design (Harper Collins Canada). 256 pages, 60.00 CAD, Cloth, 34.99 CAD, E-book.

Vanished and Vanishing Parrots: Profiling Extinct and Endangered Species. By Joseph M. Forshaw. Illustrations by Frank Knight. Foreword by Noel F. R. Snyder. 2017. Cornell University Press. 344 pages, 95.00 USD, Cloth.

Avian Cognition. Edited by Carel ten Cate and Susan D. Healy. 2017. Cambridge University Press. 348 pages, 114.95 CAD, Cloth.

The Most Perfect Thing: Inside (and Outside) a Bird's Egg. By Tim Birkhead. 2017. Bloomsbury Publishing. 296 pages, 8.99 GBP, Paper, 9.99 GBP, E-book.

Painting the Ice Bear: A Visual Investigation of Polar Bears. By Mark Adlington. 2017. University of Chicago Press. Distributed for Unicorn Press Ltd. 160 pages and 150 colour plates, 37.95 USD, Cloth.

†**Moose: Crowned Giant of the Northern Wilderness.** By Mark Raycroft. 2017. Firefly Books. 160 pages and 80 colour photographs, 19.95 CAD, Paper.

†**Great White Shark: Myth and Reality.** By Alexandre Civid-Racinais. Photographs by Patrice Héraud. 2017. Firefly Books. 144 pages and 116 colour photographs, 19.95 CAD, Paper.

***Encyclopedia of Whales, Dolphins and Porpoises.** By Erich Hoyt. 2017. Firefly Books. 300 pages, 49.95 CAD, Cloth.

Deep Thinkers: Inside the Minds of Whales, Dolphins, and Porpoises. Edited by Janet Mann. 2017. University of Chicago Press. 192 pages and 150 colour plates, 35.00 USD, Cloth, 21.00 USD, E-book.

Pacific Reef & Shore: A Photo Guide to Northwest Marine Life. By Rick M. Harbo. 2017. Harbour Publishing. 96 pages and 300 colour photographs, 12.95 CAD/USD, Paper.

Monkeytalk: Inside the Worlds and Minds of Primates. By Julia Fischer. Translated by Frederick B. Henry, Jr. 2017. University of Chicago Press. 288 pages, 25.00 USD, Cloth, 18.00 USD, E-book.

America's Snake: The Rise and Fall of the Timber Rattlesnake. By Ted Levin. 2016. University of Chicago Press. 520 pages, 35.00 USD, Cloth, 21.00 USD, E-book.

***A Natural History Study of Leech (Annelida: Clitellata: Hirudinida) Distributions in Western North America North of Mexico.** By Peter Hovingh. 2016 (Limited print version), 2017 (Digital version). Self-published. 460 pages. Freely available; the author may be contacted at phovingh@xmission.com for further information.

OTHER

†**The Magnificent Nahanni: The Struggle to Protect a Wild Place.** By Gordon Nelson. 2017. University of Regina Press. 240 pages, 34.95 CAD, Paper.

†**Curators: Behind the Scenes of Natural History Museums.** By Lance Grande. 2017. University of Chicago Press. 432 pages, 35.00 USD, Cloth, 21.50 USD, E-book.

Routledge Handbook of Ecological and Environmental Restoration. Edited by Stuart K. Allison and Stephen D. Murphy. 2017. Routledge. 604 pages, 225.00 USD, Cloth, 59.95 USD, E-book.

Biological Individuality: Integrating Scientific, Philosophical, and Historical Perspectives. Edited by Scott Lidgard and Lynn K. Nyhart. 2017. University of Chicago Press. 400 pages, 75.00 USD, Cloth, 25.00 USD, Paper or E-book.

Messages from Islands: A Global Biodiversity Tour. By Ilkka Hanski. 2016. University of Chicago Press. 272 pages, 100.00 USD, Cloth, 32.50 USD, Paper or E-book.

Hierarchy: Perspectives for Ecological Complexity. Second Edition. By T. F. H. Allen and Thomas B. Starr. 2017. University of Chicago Press. 352 pages, 125.00 USD, Cloth, 47.50 USD, Paper.

Wildness: Relations of People and Place. Edited by Gavin Van Horn and John Hausdoerffer. 2017. University of Chicago Press. Published in association with the Center for Humans and Nature, <https://www.humansandnature.org>. 272 pages, 90.00 USD, Cloth, 30.00 USD, Paper or E-book.

Common Ground: Encounters with Nature at the Edges of Life. By Rob Cowen. 2016. University of Chicago Press. 352 pages, 29.00 USD, Cloth, 18.00 USD, E-book.

Patterns in Nature: Why the Natural World Looks the Way It Does. By Philip Ball. 2016. University of Chicago Press. 288 pages and 250 colour plates, 35.00 USD, Cloth, 21.00 USD, E-book.

Orange Omelettes & Dusky Wanderers: Studies and Travels in Seychelles Over Four Decades. By Chris J. Feare. 2017. Calusa Bay Publications. 342 pages and 16 plates with colour photographs, 13.99 GBP, Paper.

The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins. By Anna Lowenhaupt Tsing. 2017. Princeton University Press. 352 pages, 29.95 USD, Cloth, 19.95 USD, Paper.

The Running Hare: The Secret Life of Farmland. By John Lewis-Stempel. 2017. Black Swan. 304 pages, 8.99 GBP, Paper.

The Serengeti Rules: The Quest to Discover How Life Works and Why It Matters. Sean B. Carroll. 2017. Princeton University Press. 263 pages, 16.95 USD, Paper.

100 Nature Hot Spots in Ontario: The Best Parks, Conservation Areas and Wild Places. By Chris Earley and Tracy C. Read. 2016. Firefly Books. 224 pages, 29.95 CAD, Paper.

The Rights of Nature: A Legal Revolution That Could Save the World. By David R. Boyd. 2017. ECW Press. 280 pages, 19.95 CAD, Paper.

The Lost Species: Great Expeditions in the Collections of Natural History Museums. By Christopher Kemp. 2017. University of Chicago Press. 256 pages, 30.00 USD, Cloth, 18.00 USD, E-book.

Our Oldest Task: Making Sense of Our Place in Nature. By Eric T. Freyfogle. 2017. University of Chicago Press. 240 pages, 45.00 USD, Cloth, 36.00 USD, E-book.

Tracks and Shadows: Field Biology as Art. By Harry W. Greene. 2016. University of California Press. 280 pages, 18.95 USD, 14.95 GBP, Paper, 18.95 USD, E-book. Cloth edition published in 2013.

Darwin's Backyard: How Small Experiments Led to a Big Theory. By James T. Costa. 2017. W.W. Norton & Co. 464 pages, 27.95 USD, Cloth.

Half-Earth: Our Planet's Fight for Life. By Edward O. Wilson. 2017. W.W. Norton & Co. 272 pages, 25.95 USD, Cloth, 16.95 USD, Paper.

The Death and Life of the Great Lakes. By Dan Egan. 2017. W.W. Norton & Co. 384 pages, 27.95 USD, Cloth.

Dynamic Forest: Man Versus Nature in the Boreal Forest. By Malcolm F. Squires. Foreword by John Kennedy Naysmith. 2017. Dundurn. 160 pages, 19.99 CAD, Paper or E-Book (PDF), 9.99 CAD, E-book (EPub).

Life at the Edge of Sight: A Photographic Exploration of the Microbial World. By Scott Chimileski and Roberto Kolter. 2017. Belknap Press. 350 pages, 35.00 USD, Cloth.

Planet of Microbes: The Perils and Potential of Earth's Essential Life Forms. By Ted Anton. 2017. University of Chicago Press. 288 pages, 25.00 USD, Cloth, 18.00 USD, E-book.

News and Comment

Upcoming Meetings and Workshops

The Committee on the Status of Endangered Wildlife in Canada

The next Wildlife Species Assessment Meeting of COSEWIC will be held 26 November–1 December 2017 at the Lord Elgin Hotel in Ottawa, Ontario. See how COSEWIC assigns status to Canadian wildlife species, the first step in protection and recovery under the federal *Species at Risk Act*. Please con-

tact ec.cosepac-cosewic.ec@canada.ca for the procedure to attend as an observer at least one week before the meeting begins. More information about COSEWIC is available at <http://www.cosewic.gc.ca>.

The Society for Integrative & Comparative Biology Annual Meeting

The Society for Integrative & Comparative Biology Annual Meeting, with the American Microscopical Society and The Crustacean Society, to be held 3–7 January 2018 at the San

Francisco Marriott Marquis, San Francisco, California. Registration is currently open. More information is available at <http://www.sicb.org/meetings/2018/index.php>.

Canadian Conference for Fisheries Research

The Canadian Conference for Fisheries Research to be held 4–7 January 2018 at the Westin Edmonton, Edmonton,

Alberta. Registration is currently open. More information is available at <http://www1.uwindsor.ca/glier/ccffr>.

Midwest Fish and Wildlife Conference

The 78th Midwest Fish and Wildlife Conference to be held 28–31 January 2018 at the Hilton Milwaukee City Center, Milwaukee, Wisconsin. The theme of the conference is: ‘Strength-

ening Natural Resources Through Collaboration’. Registration is currently open. More information is available at <http://www.midwestfw.org>.

Book Reviews

BOTANY: Ancient Pathways, Ancestral Knowledge: Ethnobotany and Ecological Wisdom of Indigenous Peoples of Northwestern North America. Volume 1: The History and Practice of Indigenous Plant Knowledge. Volume 2: The Place and Meaning of Plants in Indigenous Cultures and Worldviews — Some Useful Wild Plants: A Foraging Guide to Food and Medicine from Nature. Revised Edition	187
ZOOLOGY: Birdmania: A Remarkable Passion for Birds — Flock Together: A Love Affair with Extinct Birds — Fireflies, Glow-worms, and Lightning Bugs: Identification and Natural History of the Fireflies of the Eastern and Central United States and Canada	189
OTHER: Mourning Nature: Hope at the Heart of Ecological Loss and Grief — This River Beneath the Sky: A Year on the Platte — The Book that Changed America: How Darwin’s Theory of Evolution Ignited a Nation — The Arctic Guide: Wildlife of the Far North — Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming — The Sustainability Dilemma: Essays on British Columbia Forest and Environmental History	192
NEW TITLES	199

News and Comment

Upcoming Meetings and Workshops	
The Committee on the Status of Endangered Wildlife in Canada — The Society for Integrative & Comparative Biology Annual Meeting — Canadian Conference for Fisheries Research — Midwest Fish and Wildlife Conference	202

Mailing date of the previous issue 131(1): 30 August 2017

Has the Eastern Red-backed Salamander (<i>Plethodon cinereus</i>) declined in Ontario?	DAVID C. SEBURN and ERIN MALLON	115
Marine mammal and sea turtle sightings during a survey of the Endeavour Segment of the Juan de Fuca Ridge, British Columbia	MEIKE HOLST	120
Common Nighthawks (<i>Chordeiles minor</i>) can take off from water	LIAM P. MCGUIRE and R. MARK BRIGHAM	125
Reduced diversity and relative abundance of terrestrial snails in a Red Pine plantation compared with a surrounding Northern Red Oak – Large-toothed Aspen woods	PAUL M. CATLING and BRENDA KOSTIUK	128
Habitat use by Nuttall's Cottontails (<i>Sylvilagus nuttallii nuttallii</i>) at their northern range edge (British Columbia, Canada)	EMILY J. HERDMAN and KAREN E. HODGES	133
A review and the conservation implications of aquatic behaviour and drowning in jumping mice (Dipodidae: Zapodinae)	JENNIFER K. FREY	141
Searching for Black Swift (<i>Cypseloides niger</i>) nests in southern British Columbia	PAUL G. LEVESQUE and CHRISTINE A. ROCK	144
Short-term change in forest metrics at Grand Portage National Monument, Minnesota	SUZANNE SANDERS and JESSICA KIRSCHBAUM	151
The first record for Altai Fescue, <i>Festuca altaica</i> (Poaceae), in Nova Scotia, from an eastern alpine site on Cape Breton Island	STEPHEN DARBYSHIRE, SEAN BLANEY, and SEAN BASQUILL	164
Trends in bird densities at a remnant fescue grassland in Saskatchewan	BOHDAN PYLYPEC	170
Thematic Collection: <i>The Canadian Field-Naturalist</i> , documenting species new to Canada for nearly a century	AMANDA E. MARTIN	179

(continued on inside back cover)

ISSN 0008-3550

CAN
1824

The CANADIAN FIELD-NATURALIST

A JOURNAL OF FIELD BIOLOGY AND ECOLOGY



Volume 131, Number 3

July–September 2017

Published by THE OTTAWA FIELD-NATURALISTS' CLUB, Ottawa, Canada

The Ottawa Field-Naturalists' Club

FOUNDED IN 1879

Patron

His Excellency the Right Honourable David Johnston, C.C., C.M.M., C.O.M., C.M.
Governor General of Canada

The objectives of this Club shall be to promote the appreciation, preservation and conservation of Canada's natural heritage; to encourage investigation and publish the results of research in all fields of natural history and to diffuse information on these fields as widely as possible; to support and cooperate with organizations engaged in preserving, maintaining or restoring environments of high quality for living things.

Honorary Members

Ronald E. Bedford
Charles D. Bird
Fenja Brodo
Irwin M. Brodo
Daniel F. Brunton
Michael D. Cadman
Paul M. Catling

Francis R. Cook
Bruce Di Labio
Anthony J. Erskine
J. Bruce Falls
Peter W. Hall
Christine Hanrahan

C. Stuart Houston
Ross A. Layberry
Robert E. Lee
John McNeill
Theodore Mosquin
Robert W. Nero

E. Franklin Pope
Allan H. Reddoch
Joyce M. Reddoch
Dan Strickland
John B. Theberge
Sheila Thomson

2017 Board of Directors

President: Diane Lepage
1st Vice-President: Jakob Mueller
Recording Secretary: Lynn Ovenden
Treasurer: Ann MacKenzie

Annie Bélair
Fenja Brodo
Owen Clarkin
Edward Farnworth

Diane Kitching
Dwayne Lepitzki
Rémy Poulin
Gordon Robertson

Jeffery M. Saarela
Henry Steger
Eleanor Zurbrigg

To communicate with the Club, address postal correspondence to: The Ottawa Field-Naturalists' Club, P.O. Box 35069, Westgate P.O., Ottawa, ON, K1Z 1A2, or e-mail: ofnc@ofnc.ca. For information on Club activities, go to www.ofnc.ca

The Canadian Field-Naturalist

The *Canadian Field-Naturalist* is published quarterly by The Ottawa Field-Naturalists' Club. Opinions and ideas expressed in this journal do not necessarily reflect those of The Ottawa Field-Naturalists' Club or any other agency.

Website: www.canadianfieldnaturalist.ca/index.php/cfn

Editor-in-Chief: Dr. Dwayne Lepitzki
Copy Editors: Sandra Garland and Dr. John Wilmshurst
Book Review Editor: Barry Cottam
Subscription Manager: Eleanor Zurbrigg

Assistant Editor: Dr. Amanda Martin
Typographer: Wendy Cotie
Webmaster: Dr. Bill Halliday
Author Charges Manager: Ken Young

Associate Editors:	Dr. Ron Brooks	Dr. Jennifer R. Foote	Jon McCracken	Dr. Jeffery M. Saarela
	Dr. Carolyn Callaghan	Dr. Graham Forbes	Dr. Garth Mowat	David C. Seburn
	Dr. Paul M. Catling	Thomas S. Jung	David Nagorsen	Dr. Jeffrey H. Skevington
	Dr. François Chapeau	Dr. Donald F. McAlpine	Dr. Marty Obbard	

Chair, Publications Committee: Dr. Jeffery M. Saarela

All manuscripts intended for publication except Book Reviews can be addressed to the Editor and sent by e-mail: editor@canadianfieldnaturalist.ca **or postal mail (with disk):** P.O. Box 1979, Banff, AB T1L 1B7; (403) 762-0864. Online submissions through the website are encouraged.

Book-review correspondence should be sent to the Book Review Editor by e-mail: b.cottam@rogers.com **or postal mail:** 98 Norman Street, Ottawa, ON K1S 3K6

Subscriptions and Membership:

Subscription rates for individuals are \$40 (online only), \$50 (print only), or \$60 (print + online). Libraries and other institutions may subscribe for \$120 (online only or print only) or \$180 (print + online). All foreign print subscribers and members (including USA) must add \$10 to cover postage. The Ottawa Field-Naturalists' Club annual membership fee of \$40 (individual), \$45 (family), or \$20 (student) includes an online subscription to *The Canadian Field-Naturalist*. Members can receive printed issues of CFN for an additional \$30 per volume (four issues). For further details, see <http://ofnc.ca/membership-and-donations>. The club's regional journal, *Trail & Landscape*, covers the Ottawa District and regional Club events and field trips. It is mailed to all club members. It is available to libraries at \$40 per year. Subscriptions, applications for membership, notices of changes of address, and undeliverable copies should be sent to subscriptions@canadianfieldnaturalist.ca or mailed to: The Ottawa Field-Naturalists' Club, P.O. Box 35069, Westgate P.O., Ottawa, ON, K1Z 1A2 Canada. Canada Post Publications Mail Agreement number 40012317. Return postage guaranteed.

The Thomas H. Manning fund, a special fund of the OFNC, established in 2000 from the bequest of northern biologist Thomas H. Manning (1911–1998), provides financial assistance for the publication of papers in the CFN by independent (non-institutional) authors, with particular priority given to those addressing arctic and boreal issues. Qualifying authors should make their application for assistance from the Fund at the time of their initial submission.

COVER: Three species of shorebirds in the St. Lawrence River estuary at Kamouraska, Quebec, Canada: 13 Black-bellied Plovers (*Pluvialis squatarola*); two Red Knots (*Calidris canutus*; middle and bottom, walking to the right and behind vegetation); and a Short-billed Dowitcher (*Limnodromus griseus*; with beak under wing). See the article in this issue by Yves Turcotte, Jean-François Lamarre, and Joël Bêty, pages 203–214. Photo: Jonathan Frenette, August 2009.

Annual and Seasonal Variation in Shorebird Abundance in the St. Lawrence River Estuary during Fall Migration

YVES TURCOTTE^{1,4}, JEAN-FRANÇOIS LAMARRE^{2,3}, and JOËL BÊTY²

¹Département des sciences et techniques biologiques, Collège de La Pocatière, 140 4^e Avenue, La Pocatière, Québec G0R 1Z0 Canada

²Département de biologie et Centre d'études nordiques, Université du Québec à Rimouski, 300 Allée des Ursulines, Rimouski, Québec G5L 3A1 Canada

³Savoir Polaire Canada / Polar Knowledge Canada, Station de recherche du Canada dans l'extrême arctique / Canadian High Arctic Research Station, Cambridge Bay, Nunavut X0B 0C0 Canada

⁴Corresponding author: yturcotte@cegeplapocatiere.qc.ca

Turcotte, Yves, Jean-François Lamarre, and Joël Bêty. 2017. Annual and seasonal variation in shorebird abundance in the St. Lawrence River estuary during fall migration. *Canadian Field-Naturalist* 131(3): 203–214. <https://doi.org/10.22621/cfn.v131i3.1870>

Many North American shorebird populations are declining. It is therefore urgent to identify major sites used during their annual cycle to achieve effective conservation measures. Our objective was to expand some aspects of the knowledge base needed to assess the ecological value of the St. Lawrence River Estuary for shorebird conservation. Here, we present the results of the most intensive shorebird survey ever conducted in the St. Lawrence River Estuary during fall migration. Surveys were conducted between St-Jean-Port-Joli and St-Simon-sur-Mer, Quebec, Canada, in 2011 and 2012, from late June early July through late November, corresponding to the migration period of all species potentially present in the study area. The Semipalmated Sandpiper (*Calidris pusilla*) was one of the two most abundant species during both years of our study (most abundant species, followed by Dunlin [*Calidris alpina*] and Black-bellied Plover [*Pluvialis squatarola*] in 2011; second to Black-bellied Plover in 2012). Considering the entire shorebird community, abundance of individuals peaked in early September. Peak abundance occurred earlier for adults than for juveniles. For most species, juveniles largely outnumbered adults. Juveniles were relatively less abundant in 2012 than in 2011. This reflected a general trend observed in northeastern North America between those years, suggesting a lower breeding success in 2012. Given its importance as a staging site for juvenile birds (study area used annually by up to a few hundred thousand shorebirds) and therein, its conservation value, we recommend that the St. Lawrence River Estuary should be included within the Western Hemisphere Shorebird Reserve Network.

Key Words: *Calidris pusilla*; conservation; ecology; fall migration; migration timing; Semipalmated Sandpiper; shorebirds; St. Lawrence River Estuary; staging site; survey

Plusieurs espèces d'oiseaux de rivage étant en déclin, il importe d'identifier les sites d'importance fréquentés annuellement afin de concevoir des plans de conservation. Nous avons voulu documenter certains aspects nécessaires à l'évaluation de la valeur écologique de l'estuaire du Saint-Laurent pour ces espèces. Nous présentons les résultats de l'inventaire le plus intensif à ce jour pour l'estuaire du St-Laurent au cours de la migration automnale. Les inventaires ont été réalisés de St-Jean-Port-Joli à St-Simon-sur-Mer, Québec, Canada, en 2011 et en 2012, de la fin juin début juillet jusqu'à la fin novembre, soit pendant la période migratoire des espèces présentes dans l'aire d'étude. Le bécasseau semipalmé (*Calidris pusilla*) était l'espèce la plus abondante en 2011, suivie par le bécasseau variable (*Calidris alpina*) et le pluvier argenté (*Pluvialis squatarola*). En 2012, le pluvier argenté était l'espèce la plus abondante, suivie par le bécasseau semipalmé. Considérant l'ensemble des espèces, l'abondance des individus culminait en début septembre. L'abondance maximale des adultes précédait celle des juvéniles. Chez la plupart des espèces, les juvéniles étaient plus abondants que les adultes. Les juvéniles étaient relativement moins abondants en 2012 qu'en 2011. Cette tendance était générale dans le nord-est de l'Amérique du Nord. Cela pourrait signifier que le succès reproducteur était inférieur en 2012. Considérant son importance pour les juvéniles (l'aire d'étude pouvant être fréquentée annuellement par quelques centaines de milliers d'individus) et donc, sa valeur pour la conservation, nous proposons que l'estuaire du St-Laurent soit intégré au Réseau de réserves pour les oiseaux de rivage de l'hémisphère occidentale.

Mots-Clés: Bécasseau semipalmé; *Calidris pusilla*; chronologie de la migration; conservation; écologie; estuaire du fleuve St-Laurent; halte migratoire; inventaire; migration automnale; oiseaux de rivage

Introduction

The ecological value of the St. Lawrence River Estuary for aquatic birds has long been recognized. Several thousand breeding colonial waterbirds belonging to 12 species (e.g., Double-crested Cormorant [*Phalacroco-*

rax auritus], Razorbill [*Alca torda*], and Black-legged Kittiwake [*Rissa tridactyla*]) are found on its numerous islands (Environment Canada 2016). Migrating (e.g., Snow Goose [*Anser caerulescens*]), breeding (e.g., American Black Duck [*Anas rubripes*]), and wintering

(e.g., goldeneyes [*Bucephala* spp.]) waterfowl are also abundant (Bélanger *et al.* 1998; Gauthier *et al.* 2005; Ouellet *et al.* 2010). However, shorebird use of the St. Lawrence River Estuary has not received much attention so far and, as a result, there are few published studies documenting the biology of this taxonomic group in this ecosystem.

Indeed, we are aware of only four peer-reviewed publications dealing with shorebird use of the St. Lawrence River Estuary. Michaud and Ferron (1986, 1990) documented foraging techniques and food selection in four species of shorebirds during fall migration. Maisonneuve *et al.* (1990) conducted extensive ground surveys along the St. Lawrence system (river, estuary, and gulf) during the early part of the fall migration (late July to late August). They reported the presence of about 110 000 shorebirds belonging to 22 species in the estuarine section of their study area. As this number was the result of single counts conducted only in selected locations and moreover, before the juvenile peak of abundance for most species, it is very likely that the total number of shorebirds using the St. Lawrence River Estuary during fall migration was underestimated. More recently, Turcotte *et al.* (2013) studied seasonal change in body mass of Semipalmated Plover (*Charadrius semipalmatus*) and Semipalmated Sandpiper (*Calidris pusilla*) juveniles during fall migration. They found that mean body mass of birds captured on the southeast shore of the St. Lawrence River Estuary were similar to or higher than those of juveniles of both species captured along the North Atlantic coast.

It follows that the ecological value of the St. Lawrence River Estuary for this group has not yet been sufficiently assessed. As many North American shorebird populations are declining (Morrison *et al.* 2001; Bart *et al.* 2007; Jehl 2007; Hicklin and Chardine 2012; North American Bird Conservation Initiative Canada 2012), it is important to readily identify critical habitats and sites used during their annual cycle to achieve effective conservation objectives (Donaldson *et al.* 2000; Warnock 2010). Including the St. Lawrence River Estuary within the Western Hemisphere Shorebird

Reserve Network (Western Hemisphere Shorebird Reserve Network 2009) would likely help attain these objectives. The Western Hemisphere Shorebird Reserve Network is an international conservation strategy established in 1986 to protect key shorebird habitats. In eastern North America, along the West Atlantic flyway (also known as the Atlantic Americas flyway or Atlantic flyway), it includes Delaware Bay and two sections of the Upper Bay of Fundy. These sites are considered among the most important for shorebird conservation in the Americas. Expansion of the Western Hemisphere Shorebird Reserve Network is considered as the importance of other major candidate sites would be properly assessed and recognized (Western Hemisphere Shorebird Reserve Network 2009). Thus, our objective was to document timing of migration and abundance of southbound shorebirds using the St. Lawrence River Estuary to expand the knowledge base needed to assess the ecological value of the St. Lawrence River Estuary for their conservation. Here, we present the results of the most intensive shorebird survey ever conducted in the St. Lawrence River Estuary during fall migration.

Study Area

This study was conducted on the southeast shore of the St. Lawrence River Estuary, approximately 100 km northeast of Québec City, along a 150 km stretch of shoreline between St-Jean-Port-Joli (47.189°N, 70.296°W) and St-Simon-sur-Mer (48.205°N, 69.082°W), Quebec, Canada (Figure 1). The St. Lawrence River Estuary exhibits a strong salinity gradient west to east (Fradette and Bourget 1980; Saucier *et al.* 2009). This gradient is reflected by major changes in riparian and intertidal vegetation (Gauthier 2000) as well as in benthic invertebrate communities (Bourget 1997). Within the study area, water circulation is dominated by semi-diurnal tides that can reach over 5 m in height (Fisheries and Oceans Canada 2016). The intertidal zone may reach more than 3 km at its widest points (e.g., Ste-Anne Bay and Kamouraska Islands) according to marine charts (Natural Resources Canada 2016). Intertidal substrates are highly variable, ranging from mud-

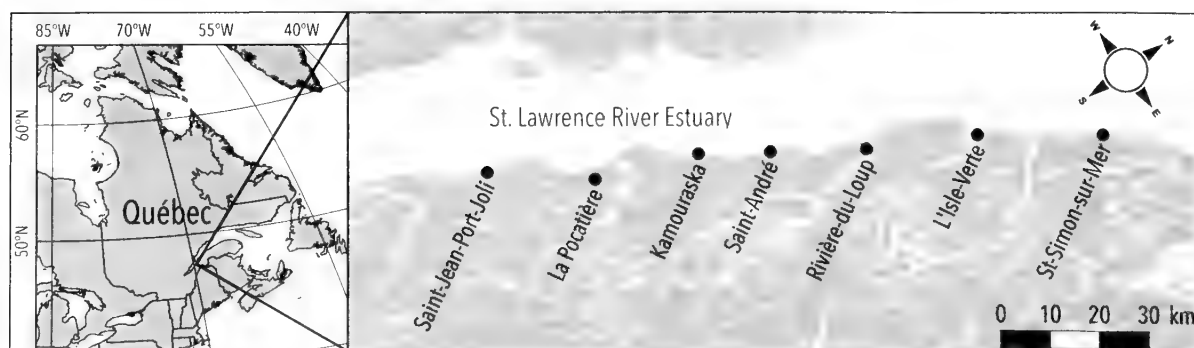


FIGURE 1. The study area on the southeast shore of the St. Lawrence River Estuary, Quebec, Canada, 2011 and 2012. Light grey areas represent the intertidal zone.

flats adjacent to American Bulrush (*Schoenoplectus americanus* (Persoon) Volk ex Schinz & R. Keller) or cordgrass (*Sporobolus* spp.) marshes in protected bays, to boulders and bare rock at exposed sites. Peregrine Falcons (*Falco peregrinus*) and Merlins (*Falco columbarius*), two important shorebird predators (Dekker *et al.* 2011), nest in and migrate through the study area. Attacks on migrating shorebirds by these predators were witnessed regularly during this study (see also Turcotte *et al.* 2013).

Methods

Shorebird Surveys

We established 30 survey sites 5 km apart along the shoreline. Each survey site corresponded to a 600 m stretch of shoreline measured with a handheld GPS at the higher high water mean tide level (the average of all higher high waters; Fisheries and Oceans Canada 2016). The higher high water mean tide level coincides with the upper limit on the shore of, depending on water salinity, American Bulrush or Smooth Cordgrass (*Sporobolus alterniflorus* (Loiseleur-Deslongchamps) P. M. Peterson & Saarela; Gauthier 2000). Thus, a total of 18 km of shoreline were covered per survey. Survey sites included all adjacent shorebird habitats above and below the shoreline (marshes, beaches, rocky shores, and tidal flats). The location of a first survey site was randomly selected to the nearest meter along a longitudinal axis within the study area. The other sites were thereafter positioned progressively every 5 km along the shoreline (systematic random sampling). In some cases, survey sites were relocated in similar habitat type, as close as possible from the selected site when, chiefly due to duck hunting activity, observer safety could have been compromised.

Based on radiotelemetry studies conducted during the non-breeding season, we assumed that this spacing would on the one hand, reduce, though certainly not eliminate, the likelihood that shorebirds would be counted in more than one survey site on a given day (see Conklin and Colwell 2007; Sprague *et al.* 2008; Obemuefemmann *et al.* 2013; Turcotte *et al.* 2013), while providing, on the other hand, as much as possible a representative coverage of the study area in order to properly describe the structure of the shorebird community. Thus, abundance values presented here should be interpreted cautiously because some “double counting” (i.e., birds counted in more than one nearby [5–15 km] survey sites not visited simultaneously) likely occurred. Conversely, “double missing” (i.e., birds missed in all nearby survey sites not visited simultaneously) would have occurred as well, counterbalancing, in an unknown proportion, double counting bias. Costly aerial surveys would have eliminated this problem. However, for most species, they would not have provided, unless supported by ground surveys, information on age class.

Surveys were conducted in 2011 and 2012 from late June–early July through late November, corresponding to the migration period of all species potentially present in the study area. Surveys were conducted every week in 2011 (21 survey weeks). In 2012, surveys were conducted every other week (11 survey weeks). During 30 min, one or two observers (same observers in both years) walked the entire 600-m survey site to ensure complete visual coverage. Shorebirds were identified with $\times 60$ spotting scopes. Age class (juveniles or adults) of shorebirds on ground was determined according to Hayman *et al.* (1986) and Paulson (2005), whenever conditions permitted (distance, light conditions, flock density, and behaviour). We surveyed sites in different tidal conditions (tidal flat covered and most birds roosting or tidal flat partly uncovered and most birds foraging) during consecutive weekly or bi-weekly surveys. Thus, it took four or five days per survey week to visit all 30 sites in requested tidal conditions. As a result, double counting and double missing were likely unavoidable.

Statistical Analyses

Statistical analyses were carried out using R version 3.3.1 (R Development Core Team 2016). Values reported are abundance (number of individuals detected) and relative abundance (%) per age class (calculated from the total number of known-age individuals detected per year). Abundance values were tested for normality (Shapiro-Wilk test; the statistical test of the null hypothesis of normality with the highest power; Ruxton *et al.* 2015) and homoscedasticity (F test). Square-root-transformation (0.5 added to data before transformation due to the presence of a value equal to 0), a transformation frequently applied to count data (Sokal and Rohlf 1995; Gotelli and Ellison 2004), was used to meet t -test assumptions. A Pearson's Chi-square test was utilized to assess the association between categorical variables.

Results

Timing of Migration

Considering the entire shorebird community, abundance of individuals peaked in early September (Tables 1 and 2, Figure 2). Shorebird juveniles initiate migration later than adults (Warnock *et al.* 2002; van de Kam *et al.* 2004). Therefore, raw values such as those appearing in Tables 1 and 2 may limit our understanding of shorebird migration dynamics. Thus, for species in which the less abundant age class included at least 2% of known age individuals (Table 3), Figure 3 (2011; weekly survey) and Figure 4 (2012; bi-weekly survey) illustrate relative abundance and timing of migration per age class. We only present species for which we were able to determine age class for at least one fourth of all individuals detected, represented by a conservative sample size (250 or more known age individuals). We thus reduced the risk of potential bias hampering

TABLE 1. Shorebird abundance per weekly survey during fall migration on the southeast shore of the St. Lawrence River Estuary, Quebec, Canada, 2011. Numbers in brackets are survey week order given a 21 consecutive week schedule.

Species	Survey week																					Total
	1 July (1)	8 July (2)	15 July (3)	22 July (4)	29 July (5)	5 Aug. (6)	12 Aug. (7)	19 Aug. (8)	26 Aug. (9)	2 Sep. (10)	9 Sep. (11)	16 Sep. (12)	23 Sep. (13)	30 Sep. (14)	7 Oct. (15)	14 Oct. (16)	21 Oct. (17)	28 Oct. (18)	4 Nov. (19)	11 Nov. (20)	18 Nov. (21)	
Nesting in the study area																						
Killdeer (<i>Charadrius vociferus</i>)	3	9	1	5	8	5	5	3	0	1	1	0	0	0	0	0	0	0	0	0	0	41
Spotted Sandpiper (<i>Actitis macularius</i>)	0	0	9	6	20	17	10	14	11	12	4	4	5	4	4	1	2	1	0	0	0	124
Wilson's Snipe (<i>Gallinago delicata</i>)	0	0	0	1	0	0	1	2	0	0	0	0	2	1	1	1	2	1	3	0	0	15
Migrating through the study area																						
Black-bellied Plover (<i>Pluvialis squatarola</i>)	0	1	0	0	5	99	718	1269	1256	626	220	60	651	533	414	92	177	136	51	2	1	6311
American Golden-Plover (<i>Pluvialis dominica</i>)	0	0	0	0	0	0	0	0	0	0	4	12	4	3	3	0	0	0	0	0	0	26
Semipalmated Plover (<i>Charadrius semipalmatus</i>)	0	0	0	36	191	206	163	349	375	643	680	211	231	104	84	114	109	2	1	0	0	3499
Solitary Sandpiper (<i>Tringa solitaria</i>)	0	0	0	0	1	1	0	0	0	0	5	2	0	0	0	0	0	0	0	0	0	9
Greater Yellowlegs (<i>Tringa melanoleuca</i>)	0	0	0	0	0	13	39	9	9	12	21	5	25	15	8	6	18	7	3	0	0	190
Lesser Yellowlegs (<i>Tringa flavipes</i>)	0	0	1	1	3	42	67	14	47	11	6	0	1	0	0	0	3	1	0	0	0	197
Whimbrel (<i>Numenius phaeopus</i>)	0	0	0	6	6	60	20	1	4	18	39	0	2	2	1	0	0	0	0	0	0	159
Hudsonian Godwit (<i>Limosa haemastica</i>)	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	1	0	0	0	0	0	7
Ruddy Turnstone (<i>Arenaria interpres</i>)	0	0	0	0	0	1	3	49	11	64	57	48	22	30	7	0	1	10	0	0	0	303
Red Knot (<i>Calidris canutus</i>)	0	0	0	0	0	0	2	17	32	54	7	0	85	48	84	0	5	0	0	0	0	334
Stilt Sandpiper (<i>Calidris himantopus</i>)	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Sanderling (<i>Calidris alba</i>)	0	0	0	0	0	2	1	21	45	78	153	186	81	31	59	71	144	117	40	30	1	1060
Dunlin (<i>Calidris alpina</i>)	0	0	0	0	0	0	0	0	0	9	11	126	4155	3589	463	82	212	167	35	0	0	8849
Baird's Sandpiper (<i>Calidris bairdii</i>)	0	0	0	0	0	0	0	0	0	2	4	0	0	0	0	0	0	0	0	0	0	6
Least Sandpiper (<i>Calidris minutilla</i>)	1	18	20	28	49	53	229	184	169	174	41	16	3	0	1	0	0	0	0	0	0	986
White-rumped Sandpiper (<i>Calidris fuscicollis</i>)	0	0	0	0	0	53	86	12	5	4	16	44	5	529	1768	635	504	351	47	67	0	4126
Pectoral Sandpiper (<i>Calidris melanotos</i>)	0	0	0	0	0	0	0	0	0	5	11	1	3	18	4	13	13	0	0	0	0	68
Semipalmated Sandpiper (<i>Calidris pusilla</i>)	0	0	0	24	72	86	78	180	3337	8059	7085	3007	391	68	12	29	10	0	0	0	0	22 438
Short-billed Dowitcher (<i>Limnodromus griseus</i>)	0	0	1	0	0	0	1	3	4	5	0	0	0	0	0	0	0	0	0	0	0	14
Yellowlegs (<i>Tringa</i> spp.)	0	0	0	0	0	30	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	36
Unidentified shorebirds	0	0	0	0	54	140	40	623	801	439	169	30	32	122	6	15	0	0	0	0	0	2471
All species	4	28	32	107	409	808	1463	2752	6106	10 222	8534	3752	5698	5103	2919	1060	1200	793	180	99	2	51 271

TABLE 2. Shorebird abundance per bi-weekly survey during fall migration on the southeast shore of the St. Lawrence River Estuary, Quebec, Canada, 2012. Numbers in brackets are survey week order given a 21 consecutive week schedule

Species	Survey week											Total
	29 June (1)	13 July (3)	27 July (5)	10 Aug. (7)	24 Aug. (9)	7 Sep. (11)	21 Sep. (13)	5 Oct. (15)	19 Oct. (17)	2 Nov. (19)	16 Nov. (21)	
Nesting in the study area												
Killdeer (<i>Charadrius vociferus</i>)	1	5	3	3	13	0	0	0	0	1	0	26
Spotted Sandpiper (<i>Actitis macularius</i>)	2	2	7	10	16	11	0	0	0	0	0	48
Wilson's Snipe (<i>Gallinago delicata</i>)	0	0	0	1	1	0	0	1	0	1	0	4
Migrating through the study area												
Black-bellied Plover (<i>Pluvialis squatarola</i>)	0	1	11	835	34	2060	627	65	30	72	0	3735
American Golden-Plover (<i>Pluvialis dominica</i>)	0	0	0	1	0	0	2	1	0	0	0	4
Semipalmated Plover (<i>Charadrius semipalmatus</i>)	0	0	71	185	238	605	251	97	125	3	0	1575
Solitary Sandpiper (<i>Tringa solitaria</i>)	0	0	0	5	2	0	0	0	0	0	0	7
Greater Yellowlegs (<i>Tringa melanoleuca</i>)	0	0	0	3	1	18	4	6	7	17	0	56
Lesser Yellowlegs (<i>Tringa flavipes</i>)	0	1	0	18	3	19	3	0	0	0	0	44
Whimbrel (<i>Numenius phaeopus</i>)	0	5	27	28	8	10	9	0	0	0	0	87
Ruddy Turnstone (<i>Arenaria interpres</i>)	0	0	1	24	6	15	24	5	2	4	0	81
Red Knot (<i>Calidris canutus</i>)	0	0	0	24	2	220	68	0	1	0	0	315
Sanderling (<i>Calidris alba</i>)	0	1	0	0	6	58	45	2	1	2	0	115
Dunlin (<i>Calidris alpina</i>)	0	0	0	0	0	47	50	24	31	216	0	368
Baird's Sandpiper (<i>Calidris bairdii</i>)	0	0	0	1	0	0	0	0	0	0	0	1
Least Sandpiper (<i>Calidris minutilla</i>)	20	66	41	281	104	28	3	0	0	0	0	543
White-rumped Sandpiper (<i>Calidris fuscicollis</i>)	0	0	6	2	1	1	0	2	51	70	0	133
Pectoral Sandpiper (<i>Calidris melanotos</i>)	0	0	0	0	6	26	59	10	11	0	0	112
Semipalmated Sandpiper (<i>Calidris pusilla</i>)	0	0	24	259	398	1188	142	30	26	0	0	2067
Short-billed Dowitcher (<i>Limnodromus griseus</i>)	0	0	0	1	0	4	0	0	0	0	0	5
Unidentified shorebirds	0	0	9	130	82	182	42	0	25	15	0	485
All species	23	81	200	1811	921	4492	1329	243	310	401	0	9811

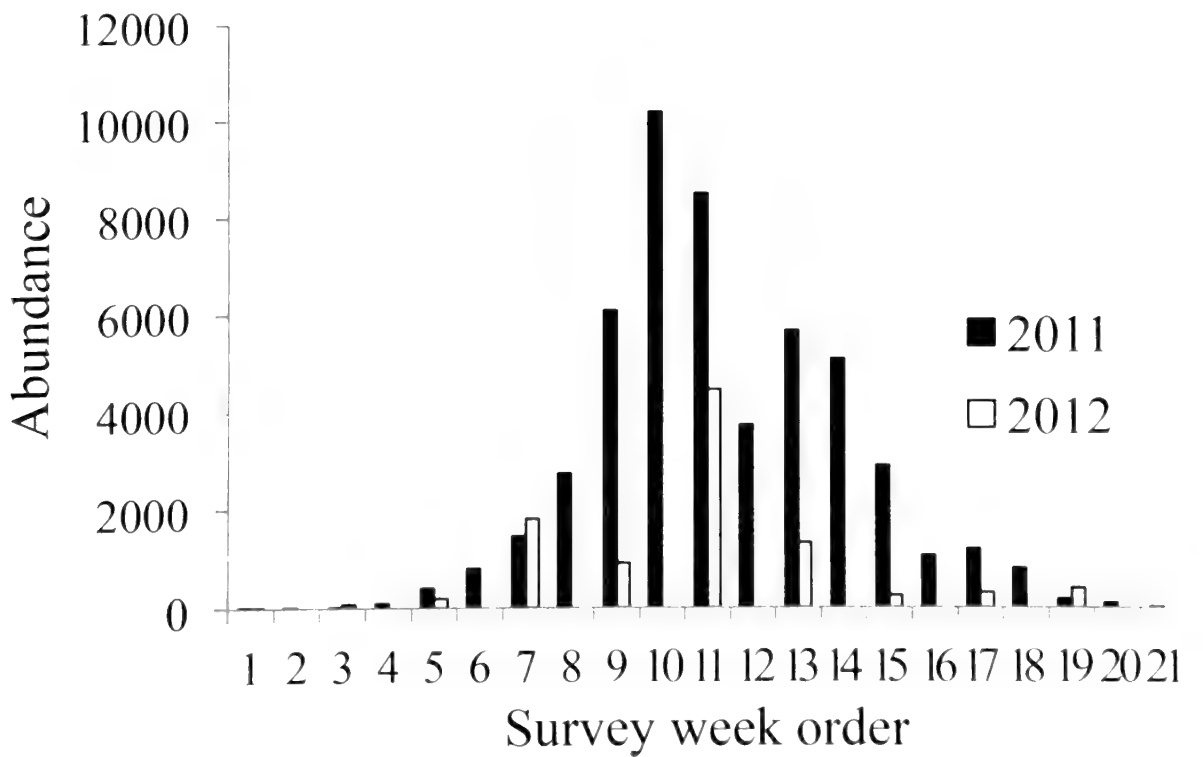


FIGURE 2. Shorebird abundance during fall migration on the southeast shore of the St. Lawrence River Estuary, Quebec, Canada, 2011(weekly survey) and 2012 (bi-weekly survey). Survey week order as in Tables 1 and 2.

TABLE 3. Relative abundance per age class of known-age shorebirds during fall migration on the southeast shore of the St. Lawrence River Estuary, Quebec, Canada, 2011 and 2012.

	2011			2012		
	<i>n</i>	Adults (%)	Juveniles (%)	<i>n</i>	Adults (%)	Juveniles (%)
Nesting in the study area						
Killdeer (<i>Charadrius vociferus</i>)	1	100.0	0.0	6	66.7	33.3
Spotted Sandpiper (<i>Actitis macularius</i>)	24	16.7	83.3	19	0.0	100.0
Wilson's Snipe (<i>Gallinago delicata</i>)	—	—	—	1	100.0	0.0
Migrating through the study area						
Black-bellied Plover (<i>Pluvialis squatarola</i>)	5188	65.7	34.3	2959	92.8	7.2
American Golden-Plover (<i>Pluvialis dominica</i>)	15	6.7	93.3	4	25.0	75.0
Semipalmated Plover (<i>Charadrius semipalmatus</i>)	2666	19.1	80.9	1408	19.1	80.9
Solitary Sandpiper (<i>Tringa solitaria</i>)	2	0.0	100.0	—	—	—
Greater Yellowlegs (<i>Tringa melanoleuca</i>)	69	18.8	81.2	27	14.8	85.2
Lesser Yellowlegs (<i>Tringa flavipes</i>)	35	34.3	65.7	6	0.0	100.0
Whimbrel (<i>Numenius phaeopus</i>)	86	65.1	34.9	69	82.6	17.4
Hudsonian Godwit (<i>Limosa haemastica</i>)	1	0.0	100.0	—	—	—
Ruddy Turnstone (<i>Arenaria interpres</i>)	285	17.9	82.1	79	32.9	67.1
Red Knot (<i>Calidris canutus</i>)	321	1.6	98.4	302	1.0	99.0
Stilt Sandpiper (<i>Calidris himantopus</i>)	—	—	—	—	—	—
Sanderling (<i>Calidris alba</i>)	906	0.2	99.8	43	2.3	97.7
Dunlin (<i>Calidris alpina</i>)	62	6.5	93.5	13	15.4	84.6
Baird's Sandpiper (<i>Calidris bairdii</i>)	2	0.0	100.0	1	0.0	100.0
Least Sandpiper (<i>Calidris minutilla</i>)	333	15.6	84.4	192	17.2	82.8
White-rumped Sandpiper (<i>Calidris fuscicollis</i>)	1202	2.2	97.8	49	22.4	77.6
Pectoral Sandpiper (<i>Calidris melanotos</i>)	17	0.0	100.0	11	0.0	100.0
Semipalmated Sandpiper (<i>Calidris pusilla</i>)	8758	2.0	98.0	964	2.5	97.5
Short-billed Dowitcher (<i>Limnodromus griseus</i>)	2	0.0	100.0	—	—	—
All species	19 975	21.6	78.4	6153	51.7	48.3

interpretation. Six species and three species met these criteria in 2011 and 2012, respectively.

Abundance

In 2011, a total of 51 271 shorebirds belonging to 22 species were detected in the 30 survey sites during the 21 weekly surveys (Table 1). In 2012, a total of 9811 shorebirds belonging to 20 species were detected in these survey sites during the 11 bi-weekly surveys (Table 2).

Semipalmated Sandpiper, one of the most abundant shorebird species in eastern North America during migration (Hicklin and Gratto-Trevor 2010), was one of the two most abundant species during both years of our study (most abundant species followed by Dunlin [*Calidris alpina*] and Black-bellied Plover [*Pluvialis squatarola*] in 2011; second to Black-bellied Plover in 2012; Tables 1 and 2).

Abundance per Age Class

Age class of 39% and 66% of shorebirds could be determined in 2011 and 2012, respectively. With the exception of Whimbrel (*Numenius phaeopus*) and Black-bellied Plover, juveniles outnumbered adults in species migrating through the study area (Table 3). Considering all species, juveniles were relatively less abundant in 2012 (48% of known-age birds) than in 2011 (78% of known-age birds; Table 3; $\chi^2_1 = 2080.1$, $P < 0.0001$).

Between-year Differences in Abundance

We observed a 64% decrease in mean shorebird abundance per survey week between 2011 ($n = 21$ weeks, 2442 birds) and 2012 ($n = 11$ weeks, 892 birds). Considering the entire migration period, when 2011 and 2012 shorebird abundances are compared on a weekly basis, this decrease was significant at the 0.05 level (paired t -test, one-tailed, $t_{10} = 2.35$, $P = 0.02$). Moreover, Figure 2 suggests that shorebird abundance from late August through October differed greatly between years, corresponding with a less abundant arrival of juveniles in 2012 than in 2011 (Table 3) and the departure of adults from our study area.

Discussion

Timing of Migration and Abundance

As expected, peak abundance occurred earlier for adults than for juveniles. The relative abundance of Semipalmated Sandpipers in the total shorebird community (46% and 22% in 2011 and 2012, respectively) was much lower than what had been reported for the Bay of Fundy (95% of all shorebirds; Hicklin 1987), a major shorebird fall staging site in eastern North America along the West Atlantic flyway. The abundance of Black-bellied Plover adults and juveniles during several weeks is also worth mentioning. The presence of numerous Black-bellied Plovers has been previously

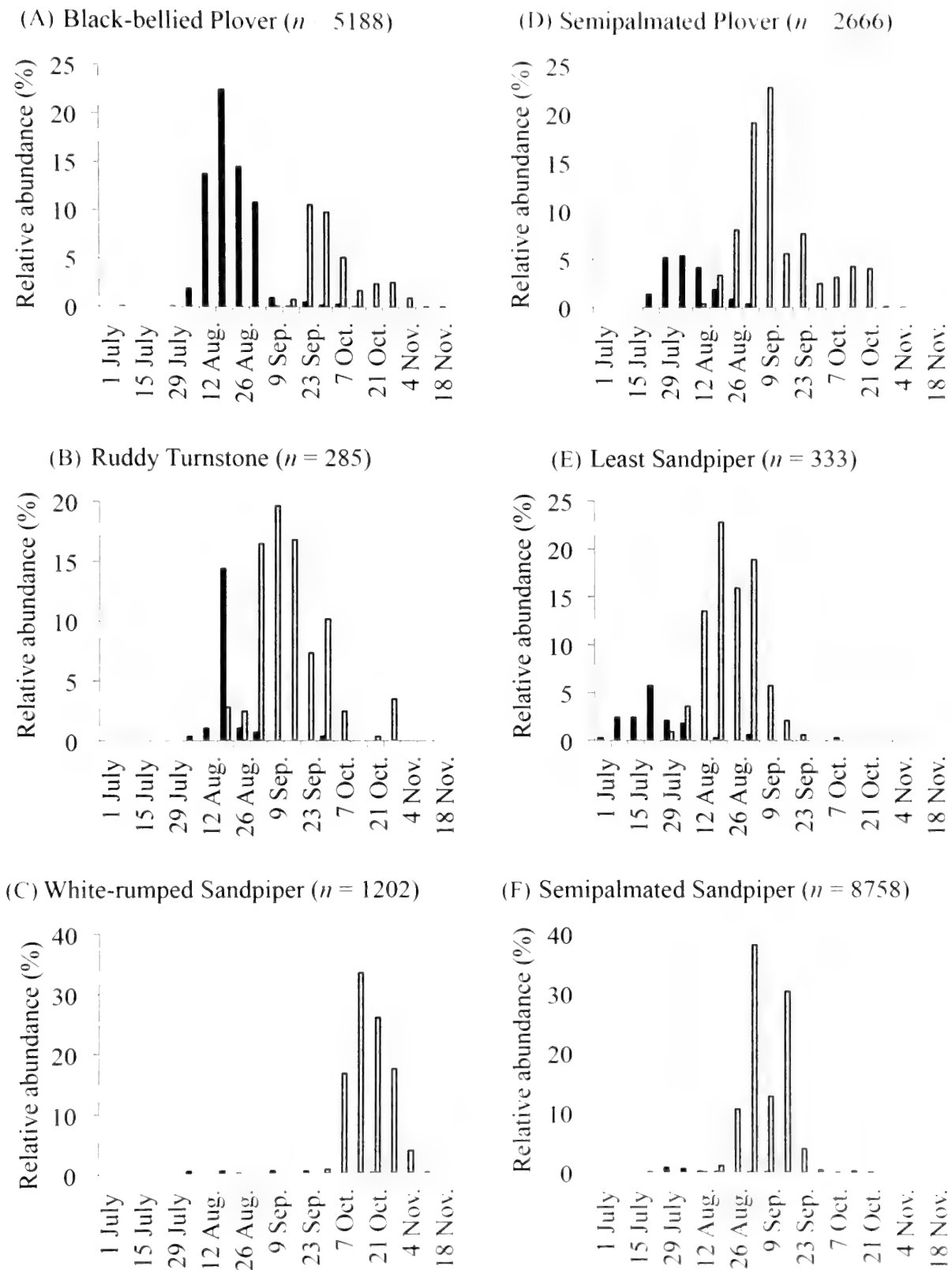


FIGURE 3. Relative abundance of some shorebird species per age class (calculated from the total number of known-age individuals detected per year; sum of all bars = 100%) during fall migration on the southeast shore of the St. Lawrence River Estuary, Quebec, Canada, 2011 (weekly survey). Solid and light grey bars represent adults and juveniles, respectively.

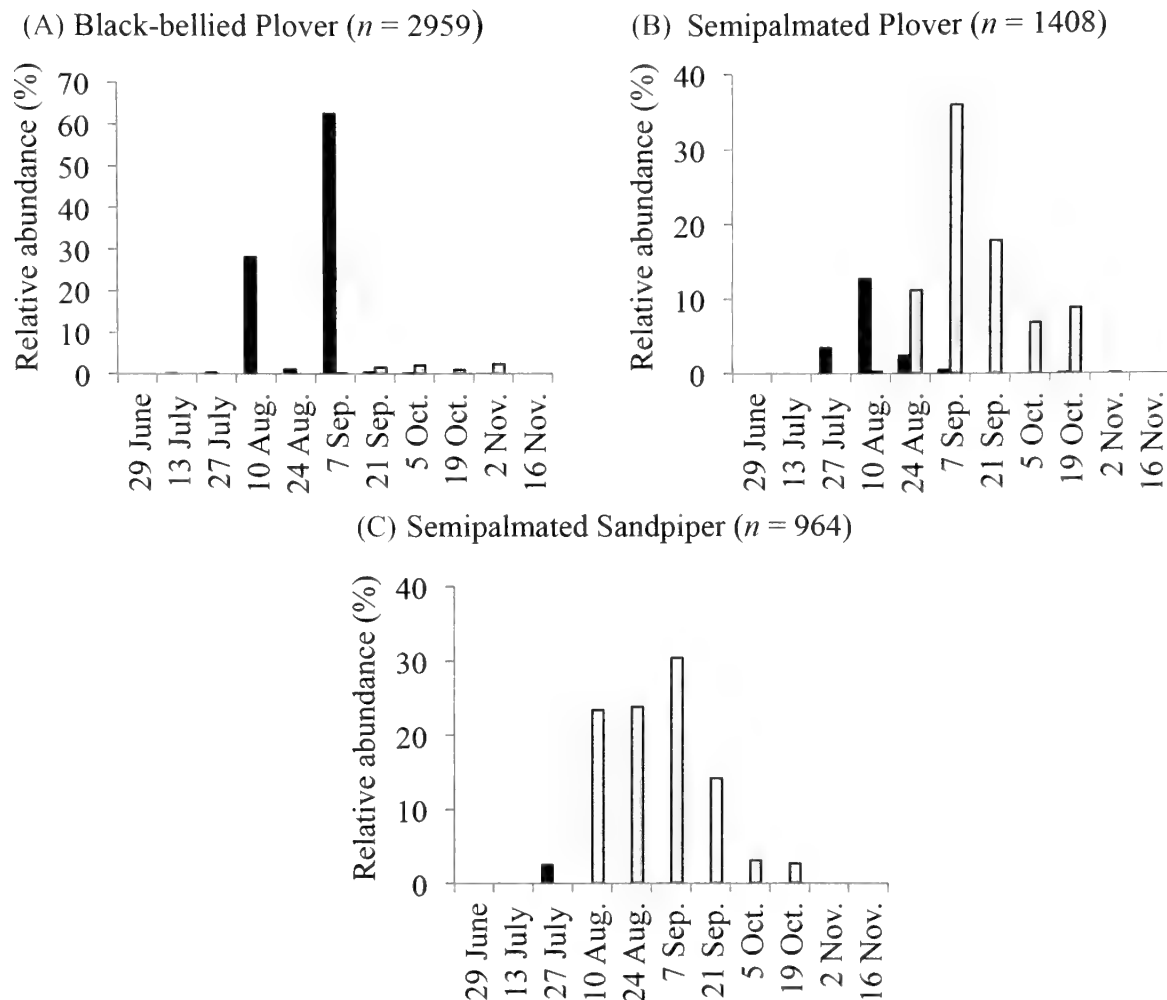


FIGURE 4. Relative abundance of some shorebird species per age class (calculated from the total number of known-age individuals detected per year; sum of all bars = 100%) during fall migration on the southeast shore of the St. Lawrence River Estuary, Quebec, Canada, 2012 (bi-weekly survey). Solid and light grey bars represent adults and juveniles, respectively.

noted near our study area during fall migration (Maison-neuve *et al.* 1990).

We do not know length of stay for most species in the St. Lawrence River Estuary. Because we consider that double counting some individuals in the survey sites between consecutive weekly or bi-weekly surveys was inevitable, it would be hazardous to extrapolate abundance values presented here to the 150 km long shoreline of our study area. Indeed, to estimate population size, survey site raw abundance values such as ours need to be corrected to take into account turnover of migrant birds between surveys (Clark *et al.* 1993; Cohen *et al.* 2009), before being extrapolated to an entire study area. Nevertheless, as shoreline covered during each survey (18 km) represented approximately 12% of total shoreline within our study area (150 km), we consider it likely that, during years of high nesting success such as 2011, a few hundred thousand shorebirds would use the study area.

Semipalmated Plover is however the only species for which published results for this study area during fall migration are available. In this species, minimal length of stay of juveniles is, on average, 12.5 days ($n = 8$; Turcotte *et al.* 2013). Based on this value and abundance of Semipalmated Plover juveniles (estimated from values in Tables 1, 2, and 3), we consider that, because survey sites were randomly selected, approximately 11 800 and 10 600 Semipalmated Plover juveniles used our study area during fall migration in 2011 and 2012, respectively. These rough estimates would represent about 5% of the estimated world population (200 000; Andres *et al.* 2012).

Abundance per Age Class

When compared to 2011, the lower relative abundance of juveniles in 2012 suggests lower breeding success on the breeding grounds for that year. Breeding output of tundra nesting birds is affected by weather conditions. Low temperatures and precipitation can af-

fect breeding density, timing of breeding, and survival of juveniles (Meltoffe *et al.* 2007; Robinson *et al.* 2014). Furthermore, pulsed resources such as rodent cycles can strongly affect nesting success (proportion of nests fledging at least one young). During low rodent abundance years, predators such as Arctic Fox (*Vulpes lagopus*), Glaucous Gull (*Larus hyperboreus*), and jaegers (*Stercorarius* spp.) rely more on alternative prey such as terrestrial bird nests and flightless juveniles (McKinnon *et al.* 2014). Most birds migrating through the St. Lawrence system likely nest at higher latitudes along the West Atlantic flyway (van de Kam *et al.* 2004; Winn *et al.* 2013; Brown *et al.* 2017). Information on nesting success at source locations within this flyway could help understand what we observed in our study area. Such data are available for 2011 and 2012 for a few study sites in the eastern Arctic, all located in Canada: Bylot Island (73.2°N, 80.0°W) and East Bay (64.0°N, 81.7°W), Nunavut, and Churchill (58.7°N, 93.8°W), Manitoba (Arctic Shorebird Demographics Network 2015). Though anecdotal, it is noteworthy that nesting success at these three sites was lower in 2012 (35%, $n = 220$) than in 2011 (52%, $n = 175$; $\chi^2_1 = 10.9$, $P = 0.001$). Moreover, particularly detailed information is available for the Bylot Island study site for both years on arctic weather conditions, rodent abundance, and terrestrial bird nesting success (Gauthier *et al.* 2013). On Bylot Island, after two years of high density, Brown Lemming (*Lemmus trimucronatus*) populations crashed in 2012 (Gauthier *et al.* 2013; Fauteux *et al.* 2016). Furthermore, 2012 was the wettest summer since 1995, contrasting with warm and sunny conditions encountered in 2011 (Gauthier *et al.* 2013). These factors likely contributed to the particularly low nesting success of shorebirds on Bylot Island in 2012 (13%) as compared to 2011 (75%; Lamarre *et al.* 2012).

Between-year Differences in Abundance

To determine whether the between-year differences we observed were a local phenomenon or a general trend in northeastern North America between 2011 and

2012, we compared our results with data corresponding to our survey weeks available from eBird (Table 4), an online citizen-science project repository for bird observation (Sullivan *et al.* 2009). We used eBird weekly average counts (average number of birds detected when encountered; eBird 2016) for coastal eastern Canada (Quebec [excluding our data], Newfoundland and Labrador, Prince Edward Island, New Brunswick, and Nova Scotia) and coastal New England (Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut). For this comparison, we only considered species for which at least 1000 individuals were detected in our study area in 2011, our high abundance reference year. Six species met this criterion, representing 90% of all individuals detected in 2011.

Data in the eBird repository are not collected following a constant effort protocol as ours nor do they present age class information. They should therefore be interpreted cautiously. Nevertheless, for most species, the decline we observed along the St. Lawrence River Estuary between 2011 and 2012 appears to have been general across both coastal eastern Canada and coastal New England (Table 4).

Ecological Value of the St. Lawrence River Estuary for Shorebird Conservation

We found that, for most species, juveniles largely outnumbered adults in the St. Lawrence River Estuary during fall migration (Table 3). For Semipalmated Sandpiper, the most abundant species in northeastern North America during fall migration, the situation reported here (~ 98% juvenile and ~ 2% adult birds) appears to differ from what is observed at two major staging sites, James Bay (Morrison 1984) and the Bay of Fundy (Hicklin 1987). James Bay and the Bay of Fundy are located approximately 1000 km northwest and 400 km southeast of the St. Lawrence River Estuary, respectively. In James Bay, Semipalmated Sandpiper juveniles are also more abundant overall than adults (juvenile peak population size in August 1982, 10 055 individuals [Morrison 1984]; adult peak population size

TABLE 4. Mean abundance in some shorebird species per survey week on the southeast shore of the St. Lawrence River Estuary, Quebec, Canada (this study), coastal eastern Canada, and coastal New England (eBird 2016), 2011 and 2012.

Species	St. Lawrence River Estuary			Coastal eastern Canada			Coastal New England		
	2011	2012	Change (%)	2011	2012	Change (%)	2011	2012	Change (%)
Black-bellied Plover (<i>Pluvialis squatarola</i>)	300.5	339.5	13	15.9	12.4	22	31.7	31.1	2
Semipalmated Plover (<i>Charadrius semipalmatus</i>)	166.6	143.2	14	21.8	24.7	13	32.7	27.7	15
Sanderling (<i>Calidris alba</i>)	50.5	10.5	79	33.0	25.9	22	74.9	67.1	10
Dunlin (<i>Calidris alpina</i>)	421.4	33.5	-92	23.7	11.2	53	33.6	22.0	34
White-rumped Sandpiper (<i>Calidris fuscicollis</i>)	196.5	12.1	-94	19.5	12.5	36	7.1	4.1	-42
Semipalmated Sandpiper (<i>Calidris pusilla</i>)	1068.5	187.9	-82	506.1	182.6	64	85.1	71.5	16

in July 1982, ~3570 individuals, estimated from Figure 13 in Morrison [1984]). By contrast, in the Bay of Fundy, the vast majority of staging birds, including Semipalmated Sandpipers, are adults (Hicklin 1987; Morrison *et al.* 1994). This suggests different migration strategies between southbound adult and juvenile birds.

The St. Lawrence River Estuary may be skipped by many adult Semipalmated Sandpipers and adults from most species, thus reducing the risk of predation when moving to an additional stopover (Ydenberg *et al.* 2002), because their body condition can take them further. In contrast, the St. Lawrence River Estuary may represent a mandatory staging site for lean juveniles trying to avoid fatal body reserve depletion before reaching the Atlantic coast. Indeed, early in their migration period, many Semipalmated Sandpiper and Semipalmated Plover juveniles weigh less than estimated mean fat-free mass at their arrival in the St. Lawrence River Estuary (Turcotte *et al.* 2013). That could be especially true for birds confronted *en route* with unpredictable winds (Shamoun-Baranes *et al.* 2010). Moreover, the St. Lawrence River Estuary may represent the last staging site for many juveniles able to accumulate sufficient body reserves to fly directly to their winter range (Hicklin 1987; Turcotte *et al.* 2013).

Based on the evidence presented here (abundance of birds [Tables 1 and 2], relative abundance of juvenile birds [Table 3]) and elsewhere (Maisonneuve *et al.* 1990; Turcotte *et al.* 2013), we recommend that, given its importance as a staging site for juvenile birds and therein, its conservation value, the St. Lawrence River Estuary, or sections of it, should be included within the Western Hemisphere Shorebird Reserve Network.

Acknowledgements

We are grateful to J.-É. Joubert and C. Pomerleau for their help in the field. M.-J. Gibson, J. R. Foote, and two anonymous reviewers improved the quality of the manuscript by their comments. We acknowledge the cooperation of several landowners for graciously allowing us land access. Y.T. received support from Fonds de recherche du Québec – Nature et technologies (FRQ-NT), Environnement et Changement climatique Canada (contract K2C55-12-2053), Comité Z.I.P. du Sud-de-l'Estuaire and Cégep de La Pocatière. J.-F.L. and J.B. received support from Fonds de recherche du Québec – Nature et technologies, Conseil de recherches en sciences naturelles et en génie du Canada (CRSNG/NSERC), and Université du Québec à Rimouski.

Literature Cited

- Andres, B. A., P. A. Smith, R. I. G. Morrison, C. L. Gratto-Trevor, S. C. Brown, and C. A. Friis. 2012. Population estimates of North American shorebirds. 2012. Wader Study Group Bulletin 119: 178–194.
- Arctic Shorebird Demographics Network. 2015. Arctic shorebird demographics network data archive. Manomet. Accessed 16 May 2016. <https://www.manomet.org/program/shorebird-recovery/arctic-shorebird-demographics-network-asdn>.
- Bart, J., S. Brown, B. Harrington, and R. I. G. Morrison. 2007. Survey trends of North American shorebirds: population declines or shifting distributions? *Journal of Avian Biology* 38: 73–82. <https://doi.org/10.1111/j.0908-8857.2007.03698.x>
- Bélanger, L., A. Reed, and J.-L. DesGranges. 1998. Reproductive variables of American Black Ducks along the St. Lawrence estuary, 1963–1991. *Canadian Journal of Zoology* 76: 1165–1173. <https://doi.org/10.1139/z98-006>
- Bourget, E. 1997. Les Animaux Littoraux du Saint-Laurent: Guide d'Identification. Les Presses de l'Université Laval, Québec, Québec, Canada.
- Brown, S., C. Gratto-Trevor, R. Porter, E. L. Weiser, D. Mizrahi, R. Bentzen, M. Boldenow, R. Clay, S. Freeman, M.-A. Giroux, E. Kwon, D. B. Lank, N. Lecomte, J. Liebezeit, V. Loverti, J. Rausch, B. K. Sandercock, S. Schulte, P. Smith, A. Taylor, B. Winn, S. Yezerinac, and R. B. Lanctot. 2017. Migratory connectivity of Semipalmated Sandpipers and implications for conservation. *Condor* 119: 207–224. <https://doi.org/10.1650/condor-16-55.1>
- Clark, K. E., L. J. Niles, and J. Burger. 1993. Abundance and distribution of migrant shorebirds in Delaware Bay. *Condor* 95: 694–705. <https://doi.org/10.2307/1369612>
- Cohen, J. B., S. M. Karpanty, J. D. Fraser, B. D. Watts, and B. R. Truitt. 2009. Residence probability and population size of Red Knots during spring stopover in the mid-Atlantic region of the United States. *Journal of Wildlife Management* 73: 939–945. <https://doi.org/10.2193/2008-042>
- Conklin, J. R., and M. A. Colwell. 2007. Diurnal and nocturnal roost site fidelity of Dunlin (*Calidris alpina pacifica*) at Humboldt Bay, California. *Auk* 124: 677–689. [https://doi.org/10.1642/0004-8038\(2007\)124\[677:danrsf\]2.0.co;2](https://doi.org/10.1642/0004-8038(2007)124[677:danrsf]2.0.co;2)
- Dekker, D., I. Dekker, D. Christie, and R. Ydenberg. 2011. Do staging Semipalmated Sandpipers spend the high-tide period in flight over the ocean to avoid falcon attacks along shore? *Waterbirds* 34: 195–201. <https://doi.org/10.1675/063.034.0208>
- Donaldson, G. M., C. Hyslop, R. I. G. Morrison, H. L. Dickson, and I. Davidson. 2000. Canadian Shorebird Conservation Plan. Environment Canada, Canadian Wildlife Service, Ottawa, Ontario, Canada.
- eBird. 2016. eBird: An online database of bird distribution and abundance. eBird, Cornell Lab of Ornithology. Accessed 2 May 2016. <http://www.ebird.org>.
- Environment Canada. 2016. Computerized database of Québec seabirds. St. Lawrence Global Observatory. Accessed 26 April 2016. <https://slgo.ca>.
- Fauteux, D., G. Gauthier, and D. Berteaux. 2016. Top-down limitation of lemmings revealed by experimental reduction of predators. *Ecology* 97: 3231–3241. <https://doi.org/10.1002/ecy.1570>
- Fisheries and Oceans Canada. 2016. Tides, currents, and water Levels. Fisheries and Oceans Canada. Accessed 26 April 2016. <http://www.waterlevels.gc.ca/eng>.
- Fradette, P., and E. Bourget. 1980. Ecology of benthic epifauna of the Estuary and Gulf of St. Lawrence: factors influencing their distribution and abundance on buoys. *Canadian Journal of Fisheries and Aquatic Sciences* 37: 979–999. <https://doi.org/10.1139/f80-127>

- Gauthier, B.** 2000. L'estuaire du Saint-Laurent: synthèse phytogéographique. Gouvernement du Québec, Ministère de l'Environnement, Direction du patrimoine écologique et du développement durable, Québec, Québec, Canada.
- Gauthier, G., J.-F. Giroux, A. Reed, A. Béchet, and L. Bélanger.** 2005. Interactions between land use, habitat use, and population increase in Greater Snow Geese: what are the consequences for natural wetlands? *Global Change Biology* 11: 856–868. <https://doi.org/10.1111/j.1365-2486.2005.00944.x>
- Gauthier, G., M.-C. Cadieux, J. Lefebvre, J. Bêty, and D. Berteaux.** 2013. Population study of greater snow geese and its nesting habitat on Bylot Island, Nunavut in 2012: a progress report. Centre d'études Nordiques, Québec City, Québec, Canada.
- Gotelli, N. J., and A. M. Ellison.** 2004. *A Primer of Ecological Statistics*. Sinauer Associates, Sunderland, Massachusetts, USA.
- Hayman, P., J. Marchant, and T. Prater.** 1986. *Shorebirds: An Identification Guide to the Waders of the World*. Houghton Mifflin Company, New York, New York, USA.
- Hicklin, P. W.** 1987. The migration of shorebirds in the Bay of Fundy. *Wilson Bulletin* 99: 540–570.
- Hicklin, P. W., and J. W. Chardine.** 2012. The morphometrics of migrant Semipalmated Sandpipers in the Bay of Fundy: evidence for declines in the eastern breeding population. *Waterbirds* 35: 74–82. <https://doi.org/10.1675/063.035.0108>
- Hicklin, P., and C. L. Gratto-Trevor.** 2010. Semipalmated Sandpiper (*Calidris pusilla*). In *The Birds of North America*. Edited by P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. Accessed 26 April 2016. <http://bna.birds.cornell.edu/bna/species/006>.
- Jehl, J. R., Jr.** 2007. Disappearance of breeding Semipalmated Sandpipers from Churchill, Manitoba: more than a local phenomenon. *Condor* 109: 351–360. [https://doi.org/10.1650/0010-5422\(2007\)109\[351:dobssf\]2.0.co;2](https://doi.org/10.1650/0010-5422(2007)109[351:dobssf]2.0.co;2)
- Lamarre, J.-F., C. Doucet, E. Bolduc, J. Bêty, and G. Gauthier.** 2012. Reproductive and migratory ecology of insectivores (shorebirds and songbirds) and the effect of climate change on insectivore-insect interactions on Bylot Island: summary report 2012. Centre d'études Nordiques, Québec City, Québec, Canada.
- Maisonneuve, C., P. Brousseau, and D. Lehoux.** 1990. Critical fall staging sites for shorebirds migrating through the St-Lawrence system. Québec. *Canadian Field-Naturalist* 104: 372–378. Accessed 28 December 2017. <https://www.biodiversitylibrary.org/item/106989?page/388&mode=1up>.
- McKinnon, L., D. Berteaux, and J. Bêty.** 2014. Predator-mediated interactions between lemmings and shorebirds: a test of the alternative prey hypothesis. *Auk* 131: 619–628. <https://doi.org/10.1642/auk-13-154.1>
- Meltofte, H., T. Piersma, H. Boyd, B. McCaffery, B. Ganter, V. V. Golovnyuk, K. Graham, C. L. Gratto-Trevor, R. I. G. Morrison, E. Nol, H.-U. Rösner, D. Schamel, H. Schekkerman, M. Y. Soloviev, P. S. Tomkovich, D. M. Tracy, I. Tulp, and L. Wenneberg.** 2007. Effects of climate variation on the breeding ecology of Arctic shorebirds. *Meddelelser om Grønland Bioscience* 59. Danish Polar Center, Copenhagen, Denmark.
- Michaud, G., et J. Ferron.** 1986. Étude comparative des techniques de quête alimentaire de quatre espèces d'oiseaux limicoles. *Naturaliste Canadien* 113: 281–292.
- Michaud, G., et J. Ferron.** 1990. Sélection des proies par quatre espèces d'oiseaux limicoles (*Charadrii*) de passage dans l'estuaire du Saint-Laurent lors de la migration vers le sud. *Canadian Journal of Zoology* 68: 1154–1162. <https://doi.org/10.1139/z90-171>
- Morrison, R. I. G.** 1984. Migration systems of some New World shorebirds. Pages 125–202 in *Behavior of Marine Animals*. Vol. 6 *Shorebirds: Migration and Foraging Behavior*. Edited by J. Burger and B. L. Olla. Plenum Press, New York, New York, USA.
- Morrison, R. I. G., C. Downes, and B. Collins.** 1994. Population trends of shorebirds on fall migration in eastern Canada 1974–1991. *Wilson Bulletin* 106: 431–447.
- Morrison, R. I. G., Y. Aubry, J. W. Butler, G. W. Beyersbergen, G. M. Donaldson, C. L. Gratto-Trevor, P. W. Hicklin, V. H. Johnston, and R. K. Ross.** 2001. Declines in North American shorebird populations. *Wader Study Group Bulletin* 94: 34–38.
- Natural Resources Canada.** 2016. The Atlas of Canada Toporama. Natural Resources Canada. Accessed 26 April 2016. <http://atlas.nrcan.gc.ca/toporama/en/index.html>.
- North American Bird Conservation Initiative Canada.** 2012. The State of Canada's Birds, 2012. Environment Canada, Ottawa, Ontario, Canada.
- Obernuefemann, K. P., J. A. Collazo, and J. E. Lyons.** 2013. Local movements and wetland connectivity at a migratory stopover of Semipalmated Sandpipers (*Calidris pusilla*) in the southeastern United States. *Waterbirds* 36: 63–76. <https://doi.org/10.1675/063.036.0110>
- Ouellet, J.-F., M. Guillemette, and M. Robert.** 2010. Spatial distribution and habitat selection of Barrow's and Common Goldeneyes wintering in the St. Lawrence marine system. *Canadian Journal of Zoology* 88: 306–314. <https://doi.org/10.1139/z09-144>
- Paulson, D. R.** 2005. *Shorebirds of North America: The Photographic Guide*. Princeton University Press, Princeton, New Jersey, USA.
- R Development Core Team.** 2016. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
- Robinson, B. G., A. Franke, and A. E. Derocher.** 2014. The influence of weather and lemmings on spatiotemporal variation in the abundance of multiple avian guilds in the Arctic. *PLoS ONE* 9(7): e101495. <https://doi.org/10.1371/journal.pone.0101495>
- Ruxton, G. D., D. M. Wilkinson, and M. Neuhäuser.** 2015. Advice on testing the null hypothesis that a sample is drawn from a normal distribution. *Animal Behaviour* 107: 249–252. <https://doi.org/10.1016/j.anbehav.2015.07.006>
- Saucier, F. J., F. Roy, S. Senneville, G. Smith, D. Lefavre, B. Zakardjian, et J.-F. Dumais.** 2009. Modélisation de la circulation dans l'estuaire et le golfe du Saint-Laurent en réponse aux variations du débit d'eau douce et des vents. *Journal of Water Science* 22: 159–176. <https://doi.org/10.7202/037480ar>
- Shamoun-Baranes, J., J. Leyrer, E. van Loon, P. Bocher, F. Robin, F. Meunier, and T. Piersma.** 2010. Stochastic atmospheric assistance and the use of emergency staging sites by migrants. *Proceedings of the Royal Society B* 277: 1505–1511. <https://doi.org/10.1098/rspb.2009.2112>
- Sokal, R. R., and F. J. Rohlf.** 1995. *Biometry*. Second edition. W. H. Freeman and Company, New York, New York, USA.
- Sprague, A. J., D. J. Hamilton, and A. W. Diamond.** 2008. Site safety and food affect movements of Semipalmated

- Sandpipers (*Calidris pusilla*) migrating through the Upper Bay of Fundy. *Avian Conservation and Ecology* 3: 4. <https://doi.org/10.5751/ace-00252-030204>
- Sullivan, B. L., C. L. Wood, M. J. Iliff, R. E. Bonney, D. Fink, and S. Kelling.** 2009. eBird: a citizen-based bird observation network in the biological sciences. *Biological Conservation* 142: 2282–2292. <https://doi.org/10.1016/j.biocon.2009.05.006>
- Turcotte, Y., J.-F. Lamarre, and J. Bêty.** 2013. Staging ecology of Semipalmated Plover (*Charadrius semipalmatus*) and Semipalmated Sandpiper (*Calidris pusilla*) juveniles in the St. Lawrence River Estuary during fall migration. *Canadian Journal of Zoology* 91: 802–809. <https://doi.org/10.1139/cjz-2013-0101>
- van de Kam, J., B. Ens, T. Piersma, and L. Zwarts.** 2004. *Shorebirds: An Illustrated Behavioural Ecology*. KNNV Publishers, Utrecht, The Netherlands.
- Warnock, N.** 2010. Stopping vs. staging: the difference between a hop and a jump. *Journal of Avian Biology* 41: 621–626. <https://doi.org/10.1111/j.1600-048x.2010.05155.x>
- Warnock, N., C. Elphick, and M. A. Rubega.** 2002. Shorebirds in the Marine Environment. Pages 581–615 in *Biology of Marine Birds*. Edited by E. A. Schreiber and J. Burger. CRC Marine Biology Series. CRC Press, Boca Raton, Florida, USA.
- Western Hemisphere Shorebird Reserve Network.** 2009. WHSRN: A Strategy for Saving Shorebirds. WHSRN Hemispheric Council. Accessed 10 June 2017. <http://www.whsrn.org>.
- Winn, B., S. Brown, C. Spiegel, D. Reynolds, and S. Johnston.** 2013. Atlantic Flyway shorebird conservation business strategy. Manomet. Accessed 17 June 2017. <https://www.manomet.org/program/shorebird-recovery/atlantic-flyway-shorebird-conservation-business-strategy>.
- Ydenberg, R. C., R. W. Butler, D. B. Lank, C. Guglielmo, M. J. F. Lemon, and N. Wolf.** 2002. Trade-offs, condition dependence and stopover site selection by migrating sandpipers. *Journal of Avian Biology* 33: 47–55. <https://doi.org/10.1034/j.1600-048x.2002.330108.x>

Received 26 October 2016

Accepted 29 August 2017

Diet of Grey Wolves (*Canis lupus*) During Calving in a Moose Caribou System in Northern Ontario

ROB FOUND^{1,3,4}, ASHLEY A. D. McLAREN¹, ARTHUR R. RODGERS², and BRENT R. PATTERSON¹

¹Ontario Ministry of Natural Resources and Forestry, Wildlife Research and Monitoring Section, Trent University, DNA Building, 2140 East Bank Drive, Peterborough, Ontario K9J 7B8 Canada

²Ontario Ministry of Natural Resources and Forestry, Centre for Northern Forest Ecosystem Research, 103–421 James Street South, Thunder Bay, Ontario P7E 2V6 Canada

³Current address: Parks Canada, Elk Island National Park, 1-54401, R.R. 203, Fort Saskatchewan, Alberta T8L 0V3 Canada

⁴Corresponding author: robert.found@pc.gc.ca

Found, Rob, Ashley A. D. McLaren, Arthur R. Rodgers, and Brent R. Patterson. 2017. Diet of Grey Wolves (*Canis lupus*) during calving in a Moose Caribou system in northern Ontario. *Canadian Field-Naturalist* 131(3): 215–220. <https://doi.org/10.22621/cfn.v131i3.1822>

Grey Wolves (*Canis lupus*) are a leading proximate cause of declining populations of Woodland Caribou (*Rangifer tarandus*), a threatened species. Although predation on adult caribou has been well documented, less is known about predation on neonatal calves. We used scat analysis to examine the diet of wolves in an area of Ontario overlapping the receding southern limit of caribou occurrence. Wolves consumed mostly Moose (*Alces americanus*; 82.7%), followed by American Beaver (*Castor canadensis*; 10.9%), caribou (3.1%), and Snowshoe Hare (*Lepus americanus*; 1.5%). This low use of caribou is consistent with other evidence suggesting that caribou are a minor dietary component of wolves in this system; however, because most caribou consumption consists of calves, the impact on this slowly reproducing species may still be significant.

Key Words: Grey Wolf; *Canis lupus*; canids; Woodland Caribou; *Rangifer tarandus*; Moose; *Alces americanus*; American Beaver; *Castor canadensis*; diet; scat; predation; human disturbance; prey selection; northern Ontario

Introduction

Grey Wolves (*Canis lupus*) are a proximate cause of declining populations of Woodland Caribou (*Rangifer tarandus*) across their shared ranges (Festa-Bianchet *et al.* 2011). The ultimate cause may be anthropogenic disturbance, seen as the proliferation of roads and other linear features and expansion of industrial forestry (Dyer *et al.* 2001). These landscape modifications can improve habitat structure for Moose (*Alces americanus*; Schneider and Wasel 2000; Bjørneraas *et al.* 2011) and wolves (Dyer *et al.* 2001; Apps and McLellan 2006) leading to increases in densities of both species (Seip 1992; Wittmer *et al.* 2007). Although wolves may target Moose as their primary prey, greater wolf density can lead to an increased frequency of incidental encounters with secondary or tertiary prey (Bergerud 1988; Seip 1992; James *et al.* 2004). The impact of this incidental predation may be negligible when the prey in question is highly productive, such as American Beaver (*Castor canadensis*) or Snowshoe Hare (*Lepus americanus*), but it can be serious for caribou, which occur in naturally low densities, reproduce slowly, and whose inherent sensitivity to human disturbance increasingly limits their distribution (Cumming *et al.* 1996; Wittmer *et al.* 2007).

The potential use of caribou by wolves in northern Ontario, Canada, is of particular interest because the Woodland Caribou Boreal population is listed as “threatened” both nationally (SARA Registry 2014) and provincially (COSSARO 2007). The southernmost range of Woodland Caribou in Ontario has been retreating

northward, and now approximates the northern extent of commercial forestry in the province (Schaefer 2003; Vors *et al.* 2007). As in other jurisdictions, human disturbance and commercial forestry activities in this mixed coniferous–deciduous forest has changed the seral composition and forest structure (Bowman *et al.* 2010) and the area now supports moderate densities of Moose and wolves, but low caribou density (Aygar *et al.* 2015).

Our objective was to determine the diversity and proportions of prey selected by wolves during the ungulate calving season in a region of Ontario where Moose, beaver, and caribou were expected to be the major prey. In particular, we wished to document the extent of wolf consumption of both adult and neonatal caribou and Moose and explore the potential for wolf predation to be a limiting factor for caribou in this area. Because of their relatively high density, we expected Moose would be the main prey item found in wolf scats. However, because of the density and prevalence of wolves across the study area, we expected caribou and beaver to be important alternative prey.

Methods

Our study focused on the Ogoki-Nakina forest in Ontario (centroid: 87.7°W, 50.5°N). Human disturbance in this area is high, with 41 km of road per 100 km² and commercial logging across 28% of the region (Thompson *et al.* 2014). The area now supports moderate densities of Moose (11.8/100 km²) and wolves (0.67/100 km²; Kittle *et al.* 2015) and a low density of caribou (minimum 0.50/100 km²; MNRF 2014). The region is

also populated by Snowshoe Hare, beaver, and other small mammals representing potential prey items for wolves.

We determined the diversity and relative proportion of prey items in wolf diets by examining scat samples and calculating percentage biomass of prey consumed (Floyd *et al.* 1978; Ciucci *et al.* 1996; Klare *et al.* 2011). We collected scats opportunistically along roads and trails between 23 May and 19 June 2012 ($n = 31$) and 2013 ($n = 70$). Scats were also collected from the territories of up to 13 wolf packs using the study area, but, because road and trail access was not equal across the entire study area, we opportunistically encountered more scats in certain areas. We minimized pseudo-replication by using both spatial and temporal separation of sampling events to reduce the likelihood of collecting multiple scats from the same individual. We analyzed only the first scat found at any location where multiple scats were deposited on the same day. Scats were located while driving along multiple roads and walking multiple trails each day and collected on 16 days. Of seven scats ultimately found to contain caribou, six were collected on different days, and all seven were also from different locations. We pooled the results from both years into a single data set ($n = 101$), to exceed the minimum ($n = 59$) recommended by Trites and Joy (2005) for inferring population-wide dietary trends.

We rinsed boiled scats in water for 2–3 minutes and air-dried them overnight. Dried, undigested matter was spread onto a grid sheet divided into 20 cells, which allowed estimates of relative proportions of diet components (i.e., coverage of one cell = 5% of scat). We expected wolves to feed mostly on mammalian prey, which are best identified using hairs found in scats (Lockie 1959; Korschgen 1980). We identified hairs visually, either unaided or microscopically, from either cuticular impression mounts or whole mounts, using a reference guide for mammalian hair in Ontario (Adorjan and Kolenosky 1969). This guide also allowed us to differentiate between calves and adults of ungulate species.

To quantify dietary variation, we recorded the frequency of occurrence of each dietary item and the percentage it contributed to total scat volume. Because increasing prey body size results in an increasing ratio of digestible to indigestible mass, the proportion of prey in scat is not representative of the relative amount of prey originally consumed (Klare *et al.* 2011). Smaller prey tend to be over-represented in scats based on volume, particularly in diets of predators whose main prey include a mix of large and small prey. Using controlled feeding trials on wolves, Weaver (1993) derived a formula to correct biases in the diets of wolves whose main prey include both very large (e.g., Moose) and smaller prey (e.g., beaver). We used that equation — mass of prey per collectable scat = $0.439 + (0.008) * (\text{body mass of prey})$ — to correct for biases in prey body size and convert percentage scat volume to per-

centage biomass in the diet. Because the formula was validated in wolf diets containing prey ranging in size from Snowshoe Hare to Moose, we calculated percentage biomass only for Moose, caribou, beaver, and hare. As data for the Weaver formula, we used the following literature-derived average body masses: Moose adult 475 kg (Quinn and Aho 1989) and calf 24 kg (at 3 weeks; Addison *et al.* 1994); caribou adult 130 kg (Kellsall 1984) and calf 10 kg (at 3 weeks; Kojola 1993); beaver, 18 kg (Hoover and Clarke 1972); and Snowshoe Hare 1.5 kg (Bennett *et al.* 2005). We calculated separate percentage biomasses for ungulate adults and calves then combined them to derive the overall percentage biomass for each ungulate species.

Results

Wolves consumed 12 identifiable dietary items, of which eight were animal and four vegetable. All scats contained some animal matter, while 38.6% contained vegetable matter. The most frequently occurring item was Moose, which was found in 51.5% of all scats, followed by beaver (38.6%), grasses (18.8%), Snowshoe Hare (9.9%), and caribou (6.9%; Figure 1). By proportion of total scat volume, Moose (44.9%) and beaver (34.4%) remained the top two dietary items, followed by caribou (6.5%), then Snowshoe Hare (6.2%). By volume, all other dietary items contributed less than 1.5% each to the total wolf diet. Total grass consumption by volume was only 1.3%, making it disproportionately frequent in scats compared to the relatively small amount of grass present. Diet items whose frequency of occurrence is relatively larger than their percentage volume may be important only in low quantities, but may also represent smaller units of prey representing incomplete meals for wolves. Black Bear (*Ursus americanus*) made up 1% of total scat volume, but this was the result of a single scat containing the only occurrence of bear. Just over half (50.5%) of all scats contained a single dietary item, 31.7% contained two dietary items, 14.9% contained three dietary items, and just 2.0% and 1.0% contained four and five dietary items, respectively.

We were able to differentiate between hairs of ungulate adults and calves and found that 15 of 52 occurrences of Moose in scats were calves (30.7% of total Moose biomass) and four of seven occurrences of caribou were calves (69.5% of total caribou biomass). Based on these biomass values, wolves consumed mostly Moose (82.7%), followed by beaver (10.9%), caribou (3.1%), and Snowshoe Hare (1.5%; Figure 2). By biomass, only 6.0% of total Moose consumption consisted of calves, but 45.2% of caribou consumption consisted of calves.

Discussion

Moose were the dominant item in the spring diet of wolves in our study area, while smaller proportions of caribou (3.1%) and beaver (10.9%) indicated that they

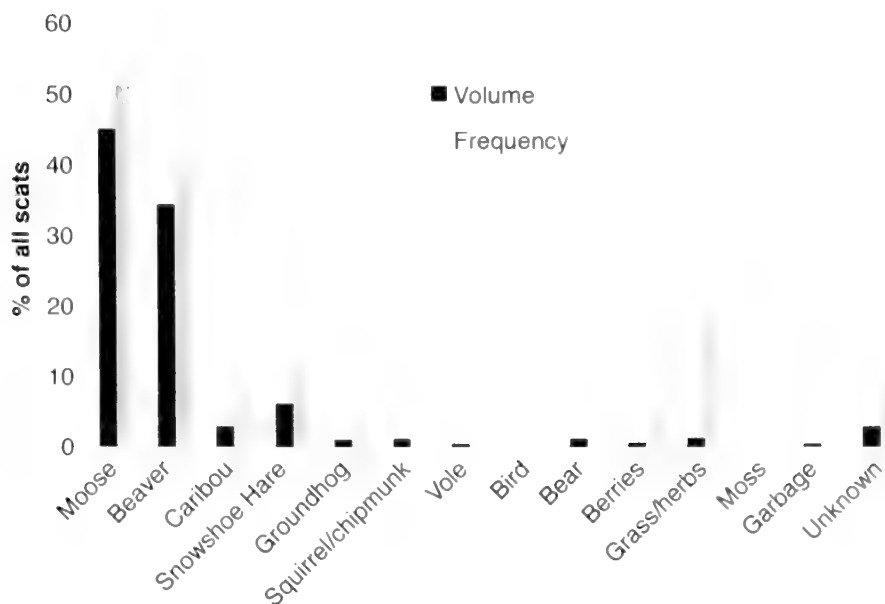


FIGURE 1. Volume and frequency of occurrence of various prey items in Grey Wolf (*Canis lupus*) scats collected in northern Ontario from late May to late June, 2012 and 2013 ($n = 101$). Differences between frequency and volume for a prey item tell us, for example, that wolves eat grass often, but not much of it. Grasses are almost always part of mixed-species scats as either a supplemental food or incidental consumption. In contrast, the biomass and frequency of caribou are similar, indicating that it is a major prey item found more often in single-prey-item scats.

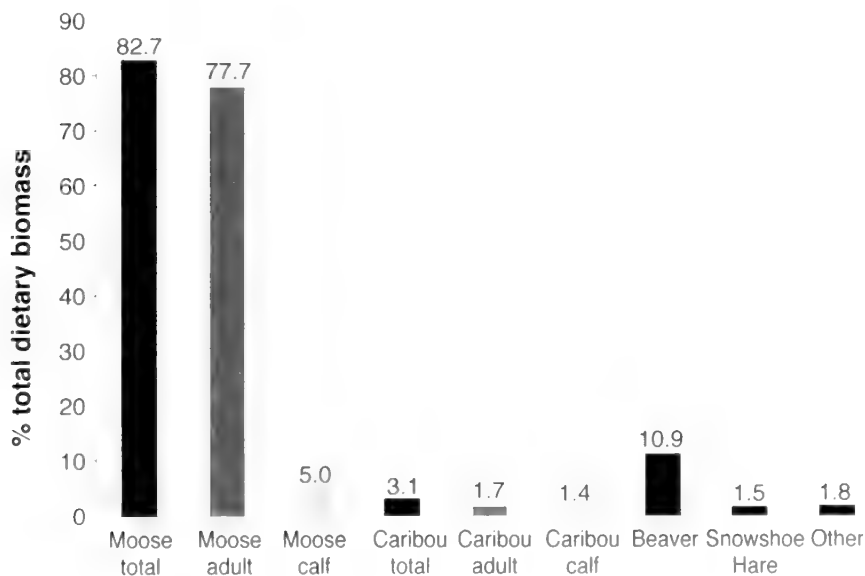


FIGURE 2. Proportion of various prey species consumed by Grey Wolves (*Canis lupus*) in northern Ontario from late May to late June, 2012 and 2013, based on calculated percentage of biomass in scat ($n = 101$).

were of less importance to wolves. These results are similar to those of other studies of spring- summer wolf diet results which ranked Moose as the main diet item, followed distantly by beaver and caribou as important alternate food sources (May–June, Ballard *et al.* 1987; May–October, Tremblay *et al.* 2001; Latham *et al.* 2011).

Selection of ungulates by wolves may correspond directly to the availability of that prey (Spaulding *et al.* 1998), but it may also be a function of increased effort and risk to wolves from hunting larger prey (Smith *et*

al. 2000). For example, in Alaska, caribou remained the primary prey even when Moose were twice as abundant (Dale *et al.* 1993). A study of wolf predation during years of changing deer density in Quebec found that Moose was the primary spring- summer prey, but deer was the primary winter prey even when they were at a much lower density than Moose (Potvin *et al.* 1988). In contrast, in our system, wolves favoured the largest ungulate available, perhaps because the ease of finding abundant Moose offset the extra effort and risk required to kill them.

Although we expected the timing of our study to be optimal for detecting consumption of ungulate calves, it may also have been optimal for predation on beaver. We found a relatively large amount of beaver in wolf diets, possibly because our study period immediately followed ice-out for beavers (when surface ice on ponds and rivers thaws enough to allow beavers to resume movement between water and land), which occurs in late April through May. Beaver are nutrition stressed at this time, which drives increased foraging activity both in and out of the water and, subsequently, increases their risk of predation (Kallemeyn *et al.* 2003). An example of this was found in northeast Alberta, where despite the availability of deer, Moose, and caribou calves, beaver were the primary prey of wolves during May and June (Latham *et al.* 2013). Wolves may also have been targeting beavers during our study.

Half of all the wolf scats we examined contained only one diet item; this is expected in diets dominated by large prey, which typically provide complete or even multiple meals for multiple wolves. Although nearly half the scats we examined contained multiple prey items, we expect that this spring–early summer prey diversity would decline with the onset of winter, with reduced availability of vegetative matter and access to prey such as beavers. Among scats containing Snowshoe Hare, all but two also contained Moose or beaver, suggesting that wolves did not rely on such small prey, but likely ate them opportunistically while targeting larger prey. Opportunism was also evident in the presence of anthropogenic garbage in one scat and Black Bear hair in another single scat. Conversely, grasses were found in low volumes (1.3%) but high frequency (18%), suggesting that they are an important dietary supplement (Ciucci *et al.* 1996). Consumption of grasses and herbs by canids is intentional and likely a way to acquire vitamins or self-treat for intestinal parasites (Mech 1970).

Moose calves made up nearly a third of all Moose biomass consumed by wolves during our study, but caribou calves made up over two-thirds of all caribou biomass consumed, which is four times what would be expected based on estimated caribou density compared with Moose density in the area. Our study period overlapped ungulate calving season, when the young are most vulnerable and generally targeted by predators (Pimlott 1974; Fritts and Mech 1981), but our results suggest that caribou calves, in particular, may have been targeted by wolves at this time. Latham *et al.* (2013) found low predation rates by wolves on caribou calves, but also greater selection by wolves of caribou-preferred habitats during calving season, which also suggested caribou calves were being specifically targeted. Results from scats collected in Alaska during May–June from wolf territories with low caribou and Moose densities showed 89.5% of total Moose consumption consisted of Moose calves, but only 15% of total caribou consumption consisted of caribou calves

(Ballard *et al.* 1987); these results were based on 40 scats collected from a single denning site. Further compounding the risk to caribou, wolves are likely not the only predators on caribou calves, as Black Bears were common in our study area. In a similar highly managed landscape in the neighbouring province of Quebec, 57% of caribou calves were killed by Black Bears, while only 4.3% were killed by wolves (Pinard *et al.* 2012).

Because wolves adjust their search images and strategies to target primary prey, secondary prey are usually hunted only incidentally (Carbyn 1987). However, when landscape changes enhance habitat for primary prey and wolf populations increase in response, rates of incidental predation on secondary prey can also increase, and mortality rates can be highest where that prey's densities are lowest (e.g., Bergerud 1988; Hayes *et al.* 2000; James *et al.* 2004).

Although caribou represented only 3.1% of the biomass consumed by wolves in early summer, given the typical low rate of increase of caribou populations, low density relative to wolf density in this system, incidental predation of caribou, and consumption of caribou calves, this may still have serious conservation implications when combined with other stressors (Wittmer *et al.* 2013; Beauchesne *et al.* 2014).

Acknowledgements

We thank the staff at the Centre for Northern Forest Ecosystem Research for logistical support in the field. Erica Newton, Jennifer Rodgers, Andrew Silver, and Scott Taylor prepared samples and analyzed the diet composition of the scats. Financial support was provided by the Forest Ecosystem Science Co-operative Inc., the Natural Sciences and Engineering Research Council, Collaborative Research and Development program, Canadian Forest Service, and the Wildlife Research and Monitoring Section and the Centre for Northern Forest Ecosystem Research of the Ontario Ministry of Natural Resources and Forestry.

Literature Cited

- Addison, E. M., R. F. McLaughlin, and J. D. Broadfoot. 1994. Growth of moose calves (*Alces alces americana*) infested and uninfested with winter ticks (*Dermacentor albipictus*). Canadian Journal of Zoology 72: 1469–1476. <https://doi.org/10.1139/z94-194>
- Adorjan, A. S., and G. B. Kolenosky. 1969. A manual for the identification of hairs of selected Ontario mammals. Research report 90. Ontario Department of Lands and Forests, Toronto, Ontario, Canada.
- Apps, C. D., and B. N. McLellan. 2006. Factors influencing the dispersion and fragmentation of endangered mountain caribou populations. Biological Conservation 130: 84–97. <https://doi.org/10.1016>
- Avgar, T., J. A. Baker, G. S. Brown, J. S. Hagens, A. M. Kittle, E. E. Mallon, M. T. McGreer, A. Mosser, S. G. Newmaster, B. R. Patterson, D. E. Reid, A. R. Rodgers, J. Shuter, G. M. Street, I. Thompson, M. J. Turetsky, P. A. Wiebe, and J. M. Fryxell. 2015. Space-use behav-

- four of woodland caribou based on a cognitive movement model. *Journal of Animal Ecology* 84: 1059–1070. <https://doi.org/10.1111/1365-2656.12357>
- Ballard, W. B., J. S. Whitman, and C. L. Gardner.** 1987. Ecology of an exploited wolf population in south-central Alaska. *Wildlife monographs* 98. Wildlife Society, Bethesda, Maryland, USA.
- Beauchesne, D., J. A. G. Jaeger, and M.-H. St. Laurent.** 2014. Thresholds in the capacity of boreal caribou to cope with cumulative disturbances: evidence from space use patterns. *Biological Conservation* 172: 190–199. <https://doi.org/10.1016/j.biocon.2014.03.002>
- Bennett, K. E., E. M. Baggs, J. R. Finney-Crawley, and M. McGrath.** 2005. An analysis of the parasites of a mid-winter population of the snowshoe hare, *Lepus americanus*, on insular Newfoundland during a cyclical peak. *Canadian Field-Naturalist* 119: 323–329. <https://doi.org/10.22621/cfn.v119i3.141>
- Bergerud, A. T.** 1988. Caribou, wolves and man. *Trends in Ecology & Evolution* 3: 68–72. [https://doi.org/10.1016/0169-5347\(88\)90019-5](https://doi.org/10.1016/0169-5347(88)90019-5)
- Björneraas, K., E. J. Solberg, I. Herfindal, B. Van Moorter, C. M. Rolandsen, J.-P. Tremblay, C. Skarpe, B.-E. Saether, R. Eriksen, and R. Astrup.** 2011. Moose *Alces alces* habitat use at multiple temporal scales in a human-altered landscape. *Wildlife Biology* 17: 44–54. <https://doi.org/10.2981/10-073>
- Bowman, J., J. C. Ray, A. J. Magoun, D. S. Johnson, and F. N. Dawson.** 2010. Roads, logging, and the large-mammal community of an eastern Canadian boreal forest. *Canadian Journal of Zoology* 88: 454–467. <https://doi.org/10.1139/z10-019>
- Carbyn, L. N.** 1987. Gray wolf and red wolf. Pages 359–376 in *Wild Furbearer Management and Conservation in North America*. Edited by M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch. Ontario Trappers Association, Toronto, Ontario, Canada.
- Ciucci, P., L. Boitani, E. R. Pelliccioni, M. Rocco, and I. Guy.** 1996. A comparison of scat-analysis methods to assess the diet of the wolf *Canis lupus*. *Wildlife Biology* 2: 37–48.
- COSSARO (Committee on the Status of Species at Risk in Ontario).** 2007. Endangered Species Act, 2007, S. O. 2007. Queen's Printer for Ontario, Toronto, Ontario, Canada.
- Cumming, H. G., D. B. Beange, and G. Lavoie.** 1996. Habitat partitioning between woodland caribou and moose in Ontario: the potential role of shared predation risk. *Rangifer* 16: 81–94. <https://doi.org/10.7557/2.16.4.1224>
- Dale, B. W., L. G. Adams, and R. T. Bowyer.** 1993. Winter wolf predation in a multiple ungulate prey system, Gates of the Arctic National Park, Alaska. Pages 223–230 in *Ecology and Conservation of Wolves in a Changing World*. Occasional publication 35. Edited by L. N. Carbyn, S. H. Fritts, and D. R. Seip. Canadian Circumpolar Institute, Edmonton, Alberta, Canada.
- Dyer, S. J., J. P. O'Neill, S. M. Wasel, and S. Boutin.** 2001. Avoidance of industrial development by woodland caribou. *Journal of Wildlife Management* 65: 531–542. <https://doi.org/10.2307/3803106>
- Festa-Bianchet, M., J. C. Ray, S. Boutin, S. D. Cote, and A. Gunn.** 2011. Conservation of caribou (*Rangifer tarandus*) in Canada: an uncertain future. *Canadian Journal of Zoology* 89: 419–434. <https://doi.org/10.1139/z11-025>
- Floyd, T. J., L. D. Mech, and P. A. Jordan.** 1978. Relating wolf scat contents to prey consumed. *Journal of Wildlife Management* 43: 528–532. <https://doi.org/10.2307/3800814>
- Fritts, S. H., and L. D. Mech.** 1981. Dynamics, movements, and feeding ecology of a newly protected wolf population in northwestern Minnesota. *Wildlife monographs* 80. Wildlife Society, Bethesda, Maryland, USA.
- Hayes, R. D., A. M. Baer, U. Wotschikowsky, and A. S. Harestad.** 2000. Kill rate by wolves on moose in Yukon. *Canadian Journal of Zoology* 78: 49–59. <https://doi.org/10.1139/z99-187>
- Hoover, W. H., and S. D. Clarke.** 1972. Fiber digestion in the beaver. *Journal of Nutrition* 102: 9–16.
- James, A. R. C., S. Boutin, D. M. Hebert, and A. B. Rippin.** 2004. Spatial separation of caribou from moose and its relation to predation by wolves. *Journal of Wildlife Management* 68: 799–809. [https://doi.org/10.2193/0022-541X\(2004\)068\[0799:SSOCFM\]2.0.CO;2](https://doi.org/10.2193/0022-541X(2004)068[0799:SSOCFM]2.0.CO;2)
- Kallemeyn, L. W., K. L. Holmberg, J. A. Perry, and B. Y. Odde.** 2003. Aquatic synthesis for Voyageurs National Park. Information and technology report 2003-0001. United States Geological Survey, Reston, Virginia, USA.
- Kelsall, J. P.** 1984. COSEWIC status report on the woodland caribou *Rangifer tarandus caribou* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, Ontario, Canada.
- Kittle, A. M., M. Anderson, T. Avgar, J. A. Baker, G. S. Brown, J. Hagens, E. Iwachewski, S. Moffat, A. Mosser, B. R. Patterson, D. E. B. Reid, A. R. Rodgers, J. Shuter, G. M. Street, I. D. Thompson, L. M. Vander Vennen, and J. M. Fryxell.** 2015. Wolves adapt territory size, not pack size to local habitat quality. *Journal of Animal Ecology* 84: 1177–1186. <https://doi.org/10.1111/1365-2656.12366>
- Klare, U., J. F. Kamler, and D. W. MacDonald.** 2011. A comparison and critique of different scat-analysis methods for determining carnivore diet. *Mammal Review* 41: 294–312. <https://doi.org/10.1111/j.1365-2907.2011.00183.x>
- Kojola, I.** 1993. Early maternal investment and growth in reindeer. *Canadian Journal of Zoology* 71: 753–758. <https://doi.org/10.1139/z93-099>
- Korschgen, L. K.** 1980. Procedure for food habits analysis. Pages 113–128 in *Wildlife Management Techniques Manual*. Edited by S. D. Schemnitz. Wildlife Society, Bethesda, Maryland, USA.
- Latham, A. D. M., M. C. Latham, M. S. Boyce, and S. Boutin.** 2013. Spatial relationships of sympatric wolves (*Canis lupus*) and coyotes (*C. latrans*) with woodland caribou (*Rangifer tarandus caribou*) during the calving season in a human-modified boreal landscape. *Wildlife Research* 40: 250–260. <https://doi.org/10.1071/WR12184>
- Latham, A. D. M., M. C. Latham, N. A. McCutchen, and S. Boutin.** 2011. Invading white-tailed deer change wolf caribou dynamics in northeastern Alberta. *Journal of Wildlife Management* 75: 204–212. <https://doi.org/10.1002/jwmg.28>
- Lockie, D.** 1959. The estimation of the food of foxes. *Journal of Wildlife Management* 23: 224–227.
- Mech, L. D.** 1970. *The Wolf: The Ecology and Behavior of an Endangered Species*. Natural History Press, Garden City, New York, New York, USA.
- MNRF (Ministry of Natural Resources and Forestry).** 2014. Integrated range assessment for woodland caribou and their habitat: Nipigon range 2010. Species at Risk Branch. MNRF, Thunder Bay, Ontario, Canada.
- Pimlott, D. H.** 1974. The ecology of the wolf in North America. Pages 280–285 in *The Wild Canids: Their Systematics*,

- Behavioral Ecology and Evolution. *Edited by* M. W. Fox. Van Nostrand-Reeinhold, New York, New York, USA.
- Pinard, V., C. Dussault, J.-P. Ouellet, D. Fortin, and R. Courtois.** 2012. Calving rate, calf survival rate, and habitat selection of forest-dwelling caribou in a highly managed landscape. *Journal of Wildlife Management* 76: 189–199. <https://doi.org/10.1002/jwmg.217>
- Potvin, F., H. Jolicœur, and J. Huot.** 1988. Wolf diet and prey selectivity during two periods for deer in Quebec: decline versus expansion. *Canadian Journal of Zoology* 66: 1274–1279. <https://doi.org/10.1139/z88-186>
- Quinn, N. W. S., and R. W. Aho.** 1989. Whole weights of moose from Algonquin Park, Ontario, Canada. *Alces* 25: 48–51.
- SARA (Species at Risk Act) Registry.** 2014. Species profile: Caribou Boreal population. Accessed 8 March 2017. http://www.sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=636.
- Schaefer, J. A.** 2003. Long-term range recession and the persistence of caribou in the taiga. *Conservation Biology* 17: 1435–1439. <https://doi.org/10.1046/j.1523-1739.2003.02288.x>
- Schneider, R. R., and S. Wasel.** 2000. The effect of settlement on the density of moose in northern Alberta. *Journal of Wildlife Management* 64: 513–520.
- Seip, D. R.** 1992. Factors limiting woodland caribou populations and their interrelationships with wolves and moose in southeastern British Columbia. *Canadian Journal of Zoology* 70: 1494–1503. <https://doi.org/10.1139/z92-206>
- Smith, D. W., L. D. Mech, M. Meagher, W. E. Clark, R. Jaffe, M. K. Phillips, and J. A. Mack.** 2000. Wolf-bison interactions in Yellowstone National Park. *Journal of Mammalogy* 81: 1128–1135. [https://doi.org/10.1644/1545-1542\(2000\)081<1128:WBIIYN>2.0.CO;2](https://doi.org/10.1644/1545-1542(2000)081<1128:WBIIYN>2.0.CO;2)
- Spaulding, R. L., P. R. Krausman, and W. B. Ballard.** 1998. Summer diet of Gray Wolves, *Canis lupus*, in northwestern Alaska. *Canadian Field-Naturalist* 112: 262–266. Accessed 23 December 2017. <https://www.biodiversitylibrary.org/item/106776#page/274/mode/1up>.
- Thompson, I. D., P. A. Wiebe, E. Mallon, A. R. Rodgers, J. M. Fryxell, J. A. Baker, and D. Reid.** 2014. Factors influencing the seasonal diet selection by woodland caribou (*Rangifer tarandus tarandus*) in boreal forests in Ontario. *Canadian Journal of Zoology* 93: 87–98. <https://doi.org/10.1139/cjz-2014-0140>
- Tremblay, J.-P., H. Jolicœur, and R. Lemieux.** 2001. Summer food habits of gray wolves in the boreal forest of the Lac Jacques-Cartier Highlands, Québec. *Alces* 37: 1–12.
- Trites, A. W., and R. Joy.** 2005. Dietary analysis from fecal samples: how many scats are enough? *Journal of Mammalogy* 86: 704–712. [https://doi.org/10.1644/1545-1542\(2005\)086\[0704:DAFFSH\]2.0.CO;2](https://doi.org/10.1644/1545-1542(2005)086[0704:DAFFSH]2.0.CO;2)
- Vors, L. S., J. A. Schaefer, B. A. Pond, A. R. Rodgers, and B. R. Patterson.** 2007. Woodland caribou extirpation and anthropogenic landscape disturbance in Ontario. *Journal of Wildlife Management* 71: 1249–1256. <https://doi.org/10.2193/2006-263>
- Weaver, J. L.** 1993. Refining the equation for interpreting prey occurrence in gray wolf scats. *The Journal of Wildlife Management* 57: 534–538.
- Wittmer, H. U., B. N. McLellan, R. Serroya, and C. D. Apps.** 2007. Changes in landscape composition influence the decline of a threatened woodland caribou population. *Journal of Animal Ecology* 76: 568–579. <https://doi.org/10.1111/j.1365-2656.2007.01220.x>
- Wittmer, H. U., R. Serrouya, L. M. Elbroch, and A. J. Marshall.** 2013. Conservation strategies for species affected by apparent competition. *Conservation Biology* 27: 254–260. <https://doi.org/10.1111/cobi.12005>

Received 7 July 2016

Accepted 7 June 2017

Observations of Long-distance Post-release Dispersal by Reintroduced Bison (*Bison bison*)

THOMAS S. JUNG^{1,3} and NICHOLAS C. LARTER²

¹Department of Environment, Government of Yukon, P.O. Box 2703, Whitehorse, Yukon Y1A 2C6 Canada

²Department of Environment and Natural Resources, Government of Northwest Territories, P.O. Box 240, Fort Simpson, Northwest Territories X0E 0N0 Canada

³Corresponding author: thomas.jung@gov.yk.ca

Jung, Thomas S., and Nicholas C. Larter. 2017. Observations of long-distance post-release dispersal by reintroduced bison (*Bison bison*). Canadian Field-Naturalist 131(3): 221–224. <https://doi.org/10.22621/cfn.v131i3.1825>

Key objectives of wildlife reintroduction projects should include encouraging post-release site fidelity and high survival rates of founding individuals. Yet, few studies empirically evaluate these performance metrics for released individuals. Bison (*Bison bison*) restoration is receiving renewed interest by wildlife managers. To inform new bison reintroduction projects, we provide an observation of a 375-km (straight-line distance) post-release movement of three bison bulls from a release site in Yukon, Canada, in 1988. In addition, we note 250-km and 155-km post-release movements of bison in the Northwest Territories, Canada, in 1980 and 1998, respectively. These observations demonstrate the dispersal ability of bison encountering new environments. Wildlife managers planning for new bison reintroductions should consider means to enhance post-release site fidelity to limit long-distance dispersal and mortality and maximize initial population growth.

Key Words: Bison; *Bison bison*; dispersal; movements; post-release; reintroduction; Yukon

The universal goal of reintroduction projects is to establish a viable population in the wild. As such, key objectives should be to encourage post-release site fidelity and high survival rates of founding individuals. Field studies (e.g., Spinola *et al.* 2008; Ryckman *et al.* 2009; Yott *et al.* 2011) and simulation modeling (Mihoub *et al.* 2011) have both demonstrated that post-release survival is negatively correlated with dispersal distance for species capable of long-distance movements. Banks *et al.* (2002) found the opposite for species with limited dispersal ability. For species with high dispersal ability, ensuring post-release site fidelity may be challenging because founding individuals lack experience with their new environment (Stamps and Swaisgood 2007) and lack resident conspecifics to encourage social attraction to a new range (Mihoub *et al.* 2011). A primary method used to increase post-release site fidelity is a soft release, where individuals are temporarily held in an *in situ* enclosure before release, in an effort to acclimatize, familiarize, and bond them to their new range. In contrast, a hard release entails releasing individuals directly onto the landscape.

Here, we report an observation of long-distance post-release dispersal among reintroduced bison (*Bison bison*) of the Aishihik population (Jung *et al.* 2015a,b) that were soft released in Yukon, Canada, during 1988–1993, and note other occurrences from the adjacent Nahanni population, which were hard released in 1980 and 1998 (Larter and Allaire 2007).

Most bison reintroductions occurred during the 1980s and early 1990s; however, there is currently renewed interest in further restoring the species to their native range (Freese *et al.* 2007; Sanderson *et al.* 2008). For

example, bison were reintroduced to Alaska in March 2015 (C. T. Seaton, personal communication) and Banff National Park in February 2017 (Steenweg *et al.* 2016; K. Heuer, personal communication). As such, historical observations of long-distance post-release dispersal may be informative for wildlife managers working on, or planning, the establishment of new bison populations.

On 17 March 1988, 20 adult bison (11 male, 9 female) were released from an enclosure 55 km west of Carmacks, Yukon, Canada (62.089°N, 136.289°W), where they had been held *in situ* since they were yearlings (1 year old in 1984) to acclimatize to local environmental conditions. This was the first release of bison into southwestern Yukon and constituted the founding of the Aishihik population (Jung *et al.* 2015a,b). Included in the inaugural release of Aishihik bison were three adult (5 year old) male bulls that were each equipped with a VHF radio-collar (Telonics, Mesa, Arizona, USA) and an individually numbered yellow ear tag (#82, #83, and #85). Their relatedness was unknown.

On 11 May 1988, the three bulls were observed together in an alpine area during an aerial telemetry flight, about 45 km west of their release site (Figure 1; P. J. Merchant, personal communication). The bulls were next seen together on 20 June 1988 about 20 km south of Beaver Creek, Yukon, on the verge of the Alaska Highway. This movement was approximately 140 km northwest of their last known location. This was the last record of #85, which was rumoured to have been killed illegally (D. R. Drummond, personal communication). During the winter of 1988–1989 the remaining two bulls, recognizable from their ear tags, were ob-

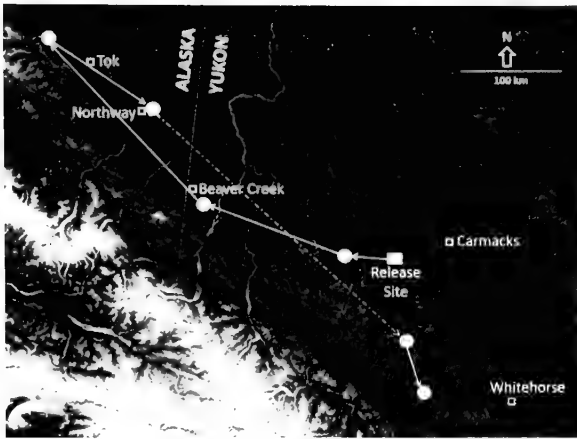


FIGURE 1. Release site (closed square), immediate post-release movements (solid lines with arrows), and subsequent translocation (dashed line) of three, then two, adult bison (*Bison bison*) bulls in Yukon and Alaska, from March 1988 to September 1989.

served variously along the Alaska Highway between the communities of Northway Junction and Tok, Alaska. During this time, they were observed by Alaskan wildlife officials as far from the release site as 45 km west of Tok (Figure 1; D. G. Kellyhouse, personal communication). Subsequently, the bulls moved back eastward along the Alaska Highway toward Northway Junction. The longest recorded straight-line distance of the bulls from their release site was about 375 km (Figure 1), which they traversed in about 6 months post-release.

While wintering near Northway Junction, the two bulls remained close to a highway roadhouse and were a concern to local residents. In late April 1989, one of the bison killed a pet dog in Northway Junction, and Alaskan wildlife officials asked their counterparts in Yukon to retrieve the two bulls. On 4 May 1989, Yukon wildlife officials captured the bulls (via chemical immobilization) in Northway Junction and transported them by truck to a release site 115 km northwest of Whitehorse, Yukon, and approximately 42 km north of the Alaska Highway (Figure 1; P. J. Merchant, personal communication). Bison #82 was last seen with #83 on 12 May 1989, near the translocation site. On 22 August 1989, #83 was seen on the Alaska Highway with a group of about 20 other bison of various sex and age classes. This bison group remained on, or adjacent to, the roadside verge for several weeks, posing a threat to highway travellers. On 13 September 1989, an adult female from the group was killed on the highway in a bison-vehicle accident. The next day, #83 was shot by wildlife officials because he would not leave the accident scene and posed a collision hazard and in an attempt to deter the rest of the group from loitering on the roadside verge (D. R. Drummond, personal communication).

Although not as well documented, similar long-distance post-release dispersals of bison from the Nahanni population apparently occurred in 1980 and 1998. In 1980, eight of 28 bison released to found the population reputedly dispersed from the release site near Nahanni Butte, Northwest Territories, southward to near Fort Nelson, British Columbia—a distance of approximately 250 km (Harper *et al.* 2000). In 1985, caribou harvesters from Trout Lake, Northwest Territories, came across tracks from what were believed to be bison on a winter road about 150 km east of the 1980 release site (Larter and Allaire 2007). In April 1998, 59 bison were released near Fort Liard, Northwest Territories, to augment the small Nahanni population, and 17 of these 59 animals also dispersed to near Fort Nelson, British Columbia, after release—a distance of approximately 155 km (Larter and Allaire 2007). The 1980 initiative was a hard release; that in 1998 was meant to be a soft release to reduce the potential for the long-distance dispersal observed in 1980, but the animals escaped from the pen shortly after arrival. The fate of these long-distance dispersing bison is unknown.

These observations are of value because they point to the extraordinary dispersal ability of post-release bison. Bison may be nomadic and, when they have not yet established their range, they may disperse long distances to areas not anticipated by wildlife managers. As remarkable as maximum recorded post-release dispersal distances of 375 km and 250 km for Aishihik and Nahanni bison may be, this behaviour is not unique to bison. For example, Yott *et al.* (2011) documented a maximum post-release dispersal distance of 142 km for reintroduced Elk (*Cervus canadensis*) in Ontario and reported other incidents involving reintroduced Elk apparently dispersing more than 300 km in Ontario-Quebec, and over 600 km in Alberta.

In addition, these observations emphasize that long-distance dispersal is risky (Bartoń *et al.* 2012; Jung 2017) and may result in losses that may be costly to the viability of small, reintroduced populations. Similarly, Yott *et al.* (2011) reported that long-distance dispersal by post-release Elk was also associated with high mortality rates, which may contribute to slow population growth. Although only a few individuals may make extreme post-release dispersals, their impact on the growth of founding populations may be pronounced. For Nahanni bison, the functional loss of eight of the founding 28 individuals likely created a lag in growth of the new population (Larter and Allaire 2007). However, long-distance dispersal is important for the long-term viability of reintroduced populations because it may facilitate range expansion into vacant habitats (Larter *et al.* 2000; Jung 2017) and gene flow among neighbouring populations.

In conclusion, anticipated bison restoration projects (e.g., Freese *et al.* 2007; Sanderson *et al.* 2008; Steenweg *et al.* 2016) should consider the post-release dis-

persal capability of bison and plan accordingly, particularly where dispersing bison may conflict with people and compromise reintroduction objectives. As suggested for Elk, wildlife managers planning bison reintroductions should consider means to enhance post-release site fidelity to limit long-distance dispersal and mortality and maximize initial population growth (Yott *et al.* 2011; Bleisch *et al.* 2017). Ryckman *et al.* (2009) suggested that post-release site fidelity may be improved for species with long-distance dispersal ability by an extended conditioning period before release (i.e., soft releases). Post-release conditioning, such as supplemental feeding over the first year or so, may also help to bond animals to a new range. Even with efforts to prevent long-distance dispersal, managers should be prepared with protocols in place to address such movements and the conflicts with humans that may ensue when bison move into areas where they are not wanted (Clark *et al.* 2016; Jung 2017). Finally, to help improve the science of reintroduction biology (Seddon *et al.* 2007; Armstrong and Seddon 2008), projects involving the release of bison onto the landscape should strive to learn more about the relationship between post-release dispersal distances, survival, and initial population growth.

Acknowledgements

We are indebted to Philip Merchant and Daniel Drummond (Yukon Department of Environment), John Nishi, (Northwest Territories Department of Environment and Natural Resources), Cormack Gates (University of Calgary), David Kellyhouse and Tom Seaton (Alaska Department of Fish and Game), and Karsten Heuer (Parks Canada), who shared their extensive first-hand experience and knowledge of bison reintroduction efforts. This work was supported by the Yukon Department of Environment and the Northwest Territories Department of Environment and Natural Resources.

Literature Cited

- Armstrong, D. P., and P. J. Seddon. 2008. Directions in reintroduction biology. *Trends in Ecology & Evolution* 23: 20–25. <https://doi.org/10.1016/j.tree.2007.10.003>
- Banks, P. B., K. Norrdahl, and E. Korpimäki. 2002. Mobility decisions and the predation risks of reintroduction. *Biological Conservation* 103: 133–138. [https://doi.org/10.1016/S0006-3207\(01\)00110-0](https://doi.org/10.1016/S0006-3207(01)00110-0)
- Bartoň, K. A., T. Hovestadt, B. L. Phillips, and J. M. J. Travis. 2012. Risky movement increases range expansion. *Proceedings of the Royal Society B* 279: 1194–1202. <https://doi.org/10.1098/rspb.2011.1254>
- Bleisch, A. D., B. J. Keller, T. W. Bonnot, L. P. Hansen, and J. J. Millspaugh. 2017. Initial movements of re-introduced elk in the Missouri Ozarks. *American Midland Naturalist* 178: 1–16. <https://doi.org/10.1674/0003-0031-178.1.1>
- Clark, D. A., L. Workman, and T. S. Jung. 2016. Impacts of reintroduced bison on First Nations people in Yukon, Canada: finding common ground through participatory research and social learning. *Conservation and Society* 14: 1–12. <https://doi.org/10.4103/0972-4923.182798>
- Freese, C. H., K. E. Aune, D. P. Boyd, J. N. Derr, S. C. Forrest, C. C. Gates, P. J. P. Gogan, S. M. Grassel, N. D. Halbert, K. Kunkel, and K. H. Redford. 2007. Second chance for the plains bison. *Biological Conservation* 136: 175–184. <https://doi.org/10.1016/j.biocon.2006.11.019>
- Harper, W. L., J. P. Elliot, I. Hatter, and H. Schwantje. 2000. Management plan for wood bison in British Columbia. British Columbia Ministry of Environment, Lands and Parks. Victoria, British Columbia, Canada.
- Jung, T. S. 2017. Extralimital movements of reintroduced bison (*Bison bison*): implications for potential range expansion and human-wildlife conflict. *European Journal of Wildlife Research* 63: 35. <https://doi.org/10.1007/s10344-017-1094-5>
- Jung, T. S., T. M. Hegel, S. A. Stotyn, and S. M. Czetwertynski. 2015a. Co-occurrence of reintroduced and resident ungulates on a shared winter range in northwestern Canada. *Écoscience* 22: 7–16. <https://doi.org/10.1080/11956860.2015.1047133>
- Jung, T. S., S. A. Stotyn, and S. M. Czetwertynski. 2015b. Dietary overlap and the potential for competition in a dynamic ungulate community in northwestern Canada. *Journal of Wildlife Management* 79: 1277–1285. <https://doi.org/10.1002/jwmg.946>
- Larter, N. C., and D. G. Allaire. 2007. History and current status of the Nahanni wood bison population. File Report 136. Department of Environment and Natural Resources, Yellowknife, Northwest Territories, Canada.
- Larter, N. C., A. R. E. Sinclair, T. Ellsworth, J. Nishi, and C. C. Gates. 2000. Dynamics of reintroduction in an indigenous large ungulate: the wood bison of northern Canada. *Animal Conservation* 2: 299–309. <https://doi.org/10.1111/j.1469-1795.2000.tb00115.x>
- Mihoub, J.-B., A. Robert, P. Le Gour, and F. Sarrazin. 2011. Post-release dispersal in animal translocations: social attraction and the “vacuum effect.” *PLoS ONE* 6: e27453. <https://doi.org/10.1371/journal.pone.0027453>
- Ryckman M. J., R. C. Rosatte, T. McIntosh, J. Hamr, and D. Jenkins. 2009. Postrelease dispersal of reintroduced elk (*Cervus elaphus*) in Ontario, Canada. *Restoration Ecology* 18: 173–180. <https://doi.org/10.1111/j.1526-100X.2009.00523.x>
- Sanderson, E. W., K. H. Redford, B. Weber, K. Aune, D. Baldes, J. Berger, D. Carter, C. Curtin, J. Derr, S. Dobrott, E. Fearn, C. Fleener, S. Forrest, C. Gerlach, C. C. Gates, J. E. Gross, P. Gogan, S. Grassel, J. A. Hilty, M. Jensen, K. Kunkel, D. Lammers, R. List, K. Minkowski, T. Olson, C. Pague, P. B. Robertson, and B. Stephenson. 2008. The ecological future of the North American bison: conceiving long-term, large-scale conservation of wildlife. *Conservation Biology* 22: 252–266. <https://doi.org/10.1111/j.1523-1739.2008.00899.x>
- Seddon, P. J., D. P. Armstrong, and R. E. Maloney. 2007. Developing the science of reintroduction biology. *Conservation Biology* 21: 303–312. <https://doi.org/10.1111/j.1523-1739.2006.00627.x>
- Spinola, R. M., T. L. Serfass, and R. P. Brooks. 2008. Survival and post-release movements of river otters translocated to western New York. *Northeastern Naturalist* 15: 13–24. [https://doi.org/10.1656/1092-6194\(2008\)15\[13:SAPMOR\]2.0.CO;2](https://doi.org/10.1656/1092-6194(2008)15[13:SAPMOR]2.0.CO;2)
- Stamp, J. A., and R. R. Swaisgood. 2007. Someplace like home: experience, habitat selection and conservation biology. *Applied Animal Behaviour Science* 102: 392–409. <https://doi.org/10.1016/j.applanim.2006.05.038>

Steenweg, R., M. Hebblewhite, D. Gummer, B. Low, and B. Hunt. 2016. Assessing potential habitat and carrying capacity for reintroduction of plains bison (*Bison bison*) in Banff National Park. PLoS One 11:e0150065 <https://doi.org/10.1371/journal.pone.0150065>

Yott, A., R. Rosatte, J. A. Schaefer, J. Hamr, and J. Fryxell. 2011. Movement and spread of a founding population of

reintroduced elk (*Cervus elaphus*) in Ontario, Canada. Restoration Ecology 101: 70–77. <https://doi.org/10.1111/j.1526-100X.2009.00639.x>

Received 11 July 2016
Accepted 26 June 2017

Observations of Notable Parental Behaviours of Northern Spotted Owls (*Strix occidentalis caurina*)

JESSE M. ALSTON^{1,2,6}, JANET E. MILLARD¹, JESSICA A. RICK^{1,3,4,5}, BRANDON W. HUSBY¹, and LAUREL A. MUNDY¹

¹Okanogan-Wenatchee National Forest, United States Forest Service, United States Department of Agriculture, 600 Sherbourne Street, Leavenworth, Washington 98826 USA

²Department of Zoology and Physiology, University of Wyoming, 1000 E University Avenue, Laramie, Wyoming 82071 USA

³Biodiversity Institute, University of Wyoming, 1000 E University Avenue, Laramie, Wyoming 82071 USA

⁴Department of Botany, University of Wyoming, 1000 E University Avenue, Laramie, Wyoming 82071 USA

⁵Program in Ecology, University of Wyoming, 1000 E University Avenue, Laramie, Wyoming 82071 USA

⁶Corresponding author: jalston@uwyo.edu

Alston, Jesse M., Janet E. Millard, Jessica A. Rick, Brandon W. Husby, and Laurel A. Mundy. 2017. Observations of notable parental behaviours of Northern Spotted Owls (*Strix occidentalis caurina*). *Canadian Field-Naturalist* 131(3): 225–227. <https://doi.org/10.22621/cfn.v131i3.1874>

Northern Spotted Owl (*Strix occidentalis caurina*) is a medium-sized forest owl of conservation concern in the Pacific Northwest of North America. We report two sightings of previously unreported parental behaviour: a Northern Spotted Owl feeding avian nestlings to its young and a Northern Spotted Owl defending a fledgling against a Black Bear (*Ursus americanus*). Further research may be warranted on the influence of brood size and habitat quality on dietary breadth. Although Black Bears have not been previously documented as Northern Spotted Owl predators, we suggest that they should be considered potential predators of nestling and fledgling owls.

Key Words: Nest predation; nest defense; diet; Northern Spotted Owl; *Strix occidentalis caurina*; Black Bear; *Ursus americanus*

Northern Spotted Owl (*Strix occidentalis caurina*) is a medium-sized owl native to western portions of northern California, Oregon, Washington, and southern British Columbia. It primarily inhabits mature forests with complex canopy structure (Forsman *et al.* 1984, 2015; LaHaye 1988; Solis and Gutierrez 1990) and preys primarily on medium-sized nocturnal rodents, such as Bushy-tailed Woodrats (*Neotoma cinerea*), Northern Flying Squirrels (*Glaucomys sabrinus*), and Red Tree Voles (*Arborimus longicaudus*; Thomas *et al.* 1990; Forsman *et al.* 2004).

In the United States, Northern Spotted Owl has been listed as “threatened” under the *Endangered Species Act* since 1990, largely because of habitat loss, and it is currently under review for increased protection because of competition with invasive Barred Owls (*Strix varia*) and other emerging threats, including disease and climate change (USFWS 2015). It has been listed as “endangered” since 2000 (COSEWIC 2008) under Canada’s *Species at Risk Act* (SARA Registry 2017) for the same reasons. United States federal agencies conduct regular monitoring of Northern Spotted Owls in areas that may be altered by management activity under a protocol established by the United States Fish and Wildlife Service (USFWS 2012). In this note, we report two observations of previously unreported parental behaviours recorded during sanctioned nest monitoring activities: a Northern Spotted Owl feeding avian nestlings to

its young and a Northern Spotted Owl defending its fledgling against a Black Bear (*Ursus americanus*).

On 26 June 2014, we observed a Northern Spotted Owl feeding avian nestlings to its young. The observation occurred when we followed an adult male Northern Spotted Owl to an active nest site about 15 km south of Leavenworth, Washington, on the Wenatchee River Ranger District of Okanogan-Wenatchee National Forest. Several passerines were mobbing the owl when we located it at 1925. At 1940, the owl took a mouse from us and led us to its mate and two fledglings. From 1940 to 2045, the pair of owls took four mice from us, delivering two of them to the fledglings, eating one, and caching the other. The male owl also brought two avian nestlings to the fledglings from outside our field of view (one at 2006, the other at 2020). The fledglings had difficulty eating the mice—repeatedly dropping them and requiring piece-by-piece feeding by the female after an hour spent attempting to eat them whole on their own—but had no difficulty eating the nestlings. This could indicate familiarity with avian prey, but it could also simply be a function of the nestlings’ size and frailty compared with mice.

The nestlings could have been retrieved from a cache or taken directly from an active nest, but they were not alive by the time they entered our view. They appeared to be in an early stage of development. Neither nestling had yet developed feathers. Both were approximately

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalists’ Club.

the size of the mice we were using to document nest status. Based on the vegetation composition of the nest stand, the size of the nestlings, and the bird songs we have heard in the area, we believe nestlings may have been American Robins (*Turdus migratorius*) or Hermit Thrushes (*Catharus guttatus*).

Northern Spotted Owls are known to feed on avian species, but these species make up only a small part of their diet: 1.4–2.8% (Hamer *et al.* 2001), 4.4–6.4% (Forsman *et al.* 2001), 4.4–5.6% (Forsman *et al.* 2004). Researchers have witnessed Northern Spotted Owls feeding on avian species (S. G. Sovern, personal communication), but, to our knowledge, Northern Spotted Owl predation on avian nestlings had not been directly observed previously. This observation indicates that avian nestlings, which are much more easily captured than adult birds, make up some portion of these owls' avian prey and are potentially a seasonally valuable resource. It is impossible to know from one observation whether this was opportunistic or selective behaviour. In either case, however, broadening of the owls' diet may have been driven in part by the increased energetic needs of owls with two nearly fledged owlets. Further research on the role of brood size in diet selection may be warranted.

This behaviour may have been driven by marginal availability of preferred prey in the breeding territory. Northern Spotted Owls have been found to prey predominantly on Bushy-tailed Woodrats and Northern Flying Squirrels in the eastern Washington Cascades (Forsman *et al.* 2001). In this area, woodrat abundance has been found to correlate well with the abundance of large snags, mistletoe brooms, and downed logs (Lehmkuhl *et al.* 2006a), while flying squirrel abundance has been found to correlate positively with canopy cover (Lehmkuhl *et al.* 2006b). We believe that this breeding territory, which has relatively little canopy or ground structure and a fairly open canopy, is unlikely to support high densities of either of these prey species. Despite the apparent unsuitability as woodrat and flying squirrel habitat, this breeding territory has been occupied (often with successful reproduction) for over a decade, indicating that either some unaccounted-for factor allows for continued high woodrat and/or flying squirrel densities or that the owls in this territory rely on other prey species.

On 7 June 2016, while visiting a different active nest site in the same area, we observed a female Northern Spotted Owl defending its fledgling from a Black Bear. We arrived at the nest site and located a fledgling owl at 2010. It was in a large Ponderosa Pine (*Pinus ponderosa* Douglas ex Lawson & C. Lawson) within 30 m of the nest, at roughly nest level (15 m above the ground). Although it was no longer in the nest, it appeared that it could not yet fly. An adult male owl arrived at 2013, and an adult female arrived shortly thereafter. At 2040, before either of the adult owls took a

mouse, a Black Bear walked through the drainage below the nest tree. The female immediately flew down toward the bear and dove to harass it. The bear continued moving down the drainage and past the nest tree to an opening downhill of it, where the bear spotted us and ran out of the stand. Although brush obscured our view of both the owl and the bear in the drainage, we saw the owl dive at the bear at least once. The female followed the bear down the drainage, roosting low enough to continue harassing the bear. She returned to the nest area only after the bear had departed the area.

Nest defense by Northern Spotted Owls has been documented in response to humans climbing nest trees or approaching owlets that had left the nest but could not fly, as well as against Common Ravens (*Corvus corax*) and Cooper's Hawks (*Accipiter cooperii*; Forsman *et al.* 1984). Researchers have also witnessed defensive behaviour against domestic dogs (J. Reid and D. Herter, personal communication) and bobcats (S. Gremel, personal communication). We found no evidence in the literature or through communication with other Northern Spotted Owl researchers that Black Bears are Northern Spotted Owl nest predators, but the female's aggressive behaviour indicates that she recognized the bear as a potential predator, and Black Bears are known predators of other young raptors (McKelvey and Smith 1979) and cavity-nesting birds (Fisher and Wiebe 2006; Tozer *et al.* 2009), even accounting for about 10% of predation events in one study of cavity-nest predation in Washington (Kozma 2011). Large, vocal owlets with limited mobility could certainly be attractive prey for foraging Black Bears. Although we believe predation on nestling and fledgling Northern Spotted Owls by Black Bears is likely uncommon, our observation coupled with known predation on the young of other raptors and cavity nesters suggests that Black Bears should, nevertheless, be considered potential predators of these young owls.

Acknowledgements

We thank the United States Forest Service (USFS) for funding Northern Spotted Owl monitoring activities. We also thank D. Youkey (USFS), S. G. Sovern (Oregon State University), P. Singleton (USFS), A. Woodrow (USFS), and M. Kuk (USFS) for helpful comments on drafts of this manuscript, and D. Herter (Raedeke Associates, Inc.), J. Reid (Bureau of Land Management), S. Andrews (Oregon State University), J. VonKienast (USFS), and S. Gremel (National Park Service) for sharing personal observations of defensive behaviour (or lack thereof) by Northern Spotted Owls.

Literature Cited

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2008. Assessment and update status report on the Spotted Owl *Strix occidentalis caurina*, *Caurina* subspecies, in Canada. COSEWIC, Ottawa, Ontario, Canada. Accessed 14 September 2017. <https://www.registre>

lep-sararegistry.gc.ca/virtual_sara/files/cosewic_sr_spotted_Owl_0808_e.pdf.

Fisher, R. J., and K. L. Wiebe. 2006. Breeding dispersal of Northern Flickers *Colaptes auratus* in relation to natural nest predation and experimentally increased perception of predation risk. *Ibis* 148: 772–781. <https://doi.org/10.1111/j.1474-919X.2006.00582.x>

Forsman, E. D., E. C. Meslow, and H. M. Wight. 1984. Distribution and biology of the Spotted Owl in Oregon. *Wildlife Monographs* 87: 3–64.

Forsman, E. D., I. A. Otto, S. G. Sovern, M. Taylor, D. W. Hays, H. Allen, S. L. Roberts, and D. E. Seaman. 2001. Spatial and temporal variation in diets of Spotted Owls in Washington. *Journal of Raptor Research* 35: 141–150.

Forsman, E. D., R. G. Anthony, E. C. Meslow, and C. J. Zabel. 2004. Diets and foraging behavior of Northern Spotted Owls in Oregon. *Journal of Raptor Research* 38: 214–230.

Forsman, E. D., S. G. Sovern, M. Taylor, and B. L. Biswell. 2015. Home range and habitat selection by Northern Spotted Owls on the eastern slope of the Cascade Mountains, Washington. *Journal of Raptor Research* 49: 109–128. <https://doi.org/10.3356/rapt-49-02-109-128.1>

Hamer, T. E., D. L. Hays, C. M. Senger, and E. D. Forsman. 2001. Diets of Northern Barred Owls and Northern Spotted Owls in an area of sympatry. *Journal of Raptor Research* 35: 221–227.

Kozma, J. M. 2011. Black Bear (*Ursus americanus*) predation on nest contents of cavity-nesting birds along the east slope Cascades. *Washington Birds* 11: 1–7.

LaHaye, W. S. 1988. Nest site selection and nesting habitat of the Northern Spotted Owl (*Strix occidentalis caurina*) in northwestern California. M.Sc. thesis, Humboldt State University, Arcata, California, USA.

Lehmkuhl, J. F., K. D. Kistler, and J. S. Begley. 2006a. Bushy-tailed Woodrat abundance in dry forests of eastern Washington. *Journal of Mammalogy* 87: 371–379. <https://doi.org/10.1644/05-MAMM-A-053R1.1>

Lehmkuhl, J. F., K. D. Kistler, J. S. Begley, and J. Boulanger. 2006b. Demography of Northern Flying Squirrels informs ecosystem management of western interior forests. *Ecological Applications* 16: 584–600. [https://doi.org/10.1890/1051-0761\(2006\)016\[0584:DONESI\]2.0.CO;2](https://doi.org/10.1890/1051-0761(2006)016[0584:DONESI]2.0.CO;2)

McKelvey, R. W., and D. W. Smith. 1979. A Black Bear in a Bald Eagle nest. *Murrelet* 60: 106–107.

SARA (Species at Risk Act) Registry. 2017. Species profile: Spotted Owl *caurina* subspecies. Accessed 14 September 2017. http://sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=33#ot18.

Solis, Jr., D. M., and R. J. Gutiérrez. 1990. Summer habitat ecology of Northern Spotted Owls in northwestern California. *Condor* 92: 739–748. <https://doi.org/10.2307/1368693>

Thomas, J. W., E. D. Forsman, J. B. Lint, E. C. Meslow, B. B. Noon, and J. Verner. 1990. A conservation strategy for the Northern Spotted Owl. Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl, Portland, Oregon, USA.

Tozer, D. C., E. Nol, D. M. Burke, K. A. Elliott, and K. J. Faulk. 2009. Predation by bears on woodpecker nests: are nestling begging and habitat choice risky business? *Auk* 126: 300–309. <https://doi.org/10.1525/auk.2009.07204>

USFWS (United States Fish and Wildlife Service). 2012. Protocol for surveying proposed management activities that may impact Northern Spotted Owls. United States Department of the Interior, Portland, Oregon, USA.

USFWS (United States Fish and Wildlife Service). 2015. Endangered and threatened wildlife and plants: 90-day findings on 10 petitions. *Federal Register* 80: 19 259–19 263.

Received 7 November 2016

Accepted 14 September 2017

Northern Snakes Appear Much More Abundant in Old Fields than in Forests

FRANCISCO RETAMAL DIAZ^{1, 2, 3} and GABRIEL BLOUIN-DEMERS¹

¹Department of Biology, University of Ottawa, 30 Marie-Curie, Ottawa, Ontario K1N 6N5 Canada

²Current address: Department of Wood and Forest Sciences, Laval University, 2405 Terrasse Street, Québec, Quebec G1V 0A6 Canada

³Corresponding author: francisco.retamal-diaz.1@ulaval.ca

Retamal Diaz, Francisco and Gabriel Blouin-Demers. 2017. Northern snakes appear much more abundant in old fields than in forests. *Canadian Field-Naturalist* 131(3): 228–234. <https://doi.org/10.22621/cfn.v131i3.1823>

Temperature is one of the most important factors regulating habitat selection by ectotherms. Through behavioural thermoregulation, reptiles maintain preferred body temperatures and thereby maximize fitness. At northern latitudes, small colubrids appear to use forest habitat rarely because of thermal constraints. In cool environments, open habitats such as old fields offer more favourable thermal conditions than forest. We studied two northern colubrid snakes, Red-bellied Snake (*Storeria occipitomaculata*) and Common Gartersnake (*Thamnophis sirtalis*), in Gatineau Park, Quebec, Canada, to test the hypothesis that small northern snakes are more abundant in open than in closed habitats because open habitats provide better opportunities for thermoregulation. Snakes were sampled using large arrays of tin and plywood coverboards. Snakes were indeed much more abundant in old fields than in forest, and fields offered more favourable thermal conditions. Most snakes were captured in spring and summer (May to August) when temperatures were highest. *Storeria occipitomaculata* preferred tin over plywood coverboards. We confirmed an apparent strong preference for open habitats in northern snakes.

Key Words: Habitat selection; behavioural thermoregulation; Common Gartersnake; *Thamnophis sirtalis*; Red-bellied Snake; *Storeria occipitomaculata*; population density; Gatineau Park

Introduction

Species face different environmental conditions across their geographic ranges, and these environmental conditions limit their distribution and abundance. The abundant centre hypothesis states that a species' abundance is highest at the centre of its geographic distribution and gradually decreases toward the edges (Brown 1984; Sagarin *et al.* 2006). At higher latitudes, abiotic factors, such as temperature and sunlight, are believed to limit abundance and distribution of terrestrial species, whereas at lower latitudes biotic factors are believed to be the main limit (Dobzhansky 1950; MacArthur 1972).

The spatial distribution of reptiles is influenced by numerous factors, such as prey density (Madsen and Shine 1996), availability of hibernation sites (Reinert and Kodrich 1982), and proximity to retreat sites (Martino *et al.* 2011). For the Squamata, temperature is considered to be one of the most important factors regulating habitat selection (Reinert 1993). In ectothermic animals, the necessity to maintain an adequate body temperature is vital for physiological and developmental processes (Peterson *et al.* 1993). Indeed, body temperature affects physiological, reproductive, and ecological performance (Huey 1982). By adjusting microhabitat selection and timing of activity, ectotherms can thermoregulate effectively (Huey *et al.* 1989; Krohmer 1989).

In northern latitudes, colubrids appear to use forest rarely, probably because of thermal constraints (Charland and Gregory 1995; Halliday and Blouin-Demers 2016). Black Ratsnakes (*Elaphe obsoleta*) prefer edges of open habitats because they provide the best opportu-

nities for thermoregulation (Blouin-Demers and Weatherhead 2001). Milksnakes (*Lampropeltis triangulum*) also prefer open habitats with high thermal quality (Row and Blouin-Demers 2006a). Habitats with high thermal quality have a minimal difference between the operative environmental temperature and the preferred body temperature of individuals. Because forest vegetation is dense and does not allow sufficient exposure to sunlight, snakes are expected to use open habitats so that they can bask and achieve preferred body temperatures (Row and Blouin-Demers 2006b).

We tested the hypothesis that small northern snakes are more abundant in open than in closed habitats because open habitats provide better opportunities for thermoregulation. More specifically, we tested the prediction that the number of captures of Common Gartersnakes (*Thamnophis sirtalis*) and Red-bellied Snakes (*Storeria occipitomaculata*), both small northern snakes, should be significantly higher in old fields than in forest. We monitored the abundance of small snakes in arrays of coverboards in old fields and in forest in Gatineau Park, Quebec, during their active season in 2015.

Coverboards are effective for sampling snakes (Grant *et al.* 1992; Houze and Chandler 2002; Ryan *et al.* 2002), particularly cryptic species (Halliday and Blouin-Demers 2015). Coverboards of different sizes (Hecnar and Hecnar 2011) and materials (Engelsoft and Ovaska 2000) can attract different species based on their microhabitat preferences (Hyde and Simons 2001). Coverboards can provide protection from predation as well as thermal benefits (Cooper *et al.* 1999; Goldsborough *et al.* 2006). Coverboards are often made of tin or plywood.

Tin was more effective than plywood for sampling Common Gartersnakes, Western Terrestrial Gartersnakes (*Thamnophis elegans*), and Sharp-tailed Snakes (*Contia tenuis*) in British-Columbia (Engelstoft and Ovaska 2000). Coverboards are preferred over traps because they are economical and safe (Ryan *et al.* 2002). A secondary objective of our study was to quantify the efficacy of tin and plywood coverboards at attracting small snakes.

Methods

We sampled snakes at four sites in Gatineau Park (45.50°N, 76.00°W), Quebec, in summer 2015. All sites were less than 25 km apart. Although Red-bellied Snake, Common Gartersnake, Smooth Greensnake (*Liochlorophis vernalis*), Ring-necked Snake (*Diadophis punctatus*), and Milksnake (*Lampropeltis triangulum*) were all captured, we only obtained sufficient captures for analysis of Common Gartersnake and Red-bellied Snake. At each of the four sites, we set up two 200-m transects with pairs of coverboards (one roofing tin, one 3/4-inch [2-cm] plywood, both 90 × 60 cm) installed every 10 m, for a total of 320 coverboards. At each site, the transects were parallel to and 50 m from the edge between old field and forest, one transect in the field and one transect in the forest. The plant community in the old fields consisted mainly of *Aster* sp., *Rhamnus* sp., *Asclepias* sp., *Cirsium* sp., and *Poa* spp. All forests were mostly composed of White Birch (*Betula papyrifera* Marshall), Sugar Maple (*Acer saccharum* Marshall), and American Beech (*Fagus grandifolia* Ehrhart). Detailed site descriptions and photographs are available in Appendix S1.

We sampled snakes weekly from 14 May to 16 November 2015. The four sites were visited on the same sunny day between 0800 and 1800 with a weekly rotation in the order in which sites were visited so that they were visited at different times of day. Snakes were hand captured from under the coverboards and each individual was marked by branding one ventral scale with a medical cautery unit (Bovie Aaron Low-Temp Reusable Cautery Unit, Clearwater, Florida, USA; Winne *et al.* 2006). The date, time, air temperature (at about waist height), temperature under the coverboard, coverboard type (tin or plywood), and habitat type (forest or old field) were recorded for each capture. Individuals were then released immediately at their point of capture. We placed 18 temperature data loggers (iButton thermochron, model DS1921L, Dallas, Sunnyvale, California, USA) under coverboards of both materials and in both habitats at the four sites. The loggers were programmed to measure temperature on the hour between 0800 and 1800 for two periods: from 12 May to 30 July and from 10 September to 23 October.

For both species, we compared the total number of snakes captured (including recaptures) in forest with those captured in field and the total number of snakes

captured under tin with those captured under plywood using generalized linear mixed-effects models with a Poisson distribution in R (R Core Team 2012; package lme4; function glmer; family Poisson; Bates *et al.* 2012). We used a Poisson distribution because the data were zero inflated. Month, habitat, time of capture, ambient temperature, coverboard material, and all interactions were fixed effects, and site identity was a random effect. We compared maximum temperature under tin and plywood coverboards in forest and old field using a linear mixed-effects model in R (package nlme; function lme; Pinheiro *et al.* 2012). Habitat, cover type, and all interactions were fixed effects and site identity was a random effect.

Results

We captured 353 snakes (including recaptures) of five species during the 25 weekly visits. Captures remained constant from May until late August and then decreased slowly until November. Common Gartersnakes ($n = 90$) and Red-bellied Snakes ($n = 242$) were the two most abundant species. Rarer species included Smooth Greensnake ($n = 2$), Ring-necked Snake ($n = 2$), and Milksnake ($n = 17$). Total unique captures comprised two Ring-necked Snakes, two Smooth Greensnakes, 13 Milksnakes, 57 Common Gartersnakes, and 171 Red-bellied Snakes.

Controlling for the effects of month, site, and time of capture, we captured significantly more Common Gartersnakes ($z = 4.47$, $P < 0.001$) and Red-bellied Snakes ($z = 9.196$, $P < 0.001$) in the field than in forest (Figure 1). In fact, only one Common Gartersnake and seven Red-bellied Snakes were captured in forest. We also captured more snakes in mid-season (June to July) than in early (May) and in late season (September to November): Common Gartersnake: $z = 2.42$, $P = 0.016$; Red-bellied Snake: $z = 2.875$, $P = 0.004$ (Figure 2). Whereas Common Gartersnakes did not seem to have a preference between tin and plywood coverboards ($z = 0.11$, $P = 0.91$; Figure 1), we captured more Red-bellied Snakes under tin than plywood coverboards ($z = 5.78$, $P < 0.001$; Figure 1).

Temperature did not vary significantly between plywood and tin coverboards ($t = 0.16$, $P = 0.87$; Figure 3). Temperature varied significantly between coverboards in forest and those in fields only during the warmer months (May, June, and July). During these months, temperatures under coverboards in fields were on average 8.8°C higher than under coverboards in forest ($t = 3.46$, $P < 0.001$; Figure 3). Coverboards in forests never warmed to the preferred temperature range of either Red-bellied Snakes (about 26.5°C; Brattstrom 1965) or Common Gartersnakes (24.5°–30.7°C; Peterson *et al.* 1987; 25.5 ± 0.4°C [SE] to 27.4 ± 0.3°C, Halliday and Blouin-Demers 2016; Figure 3).

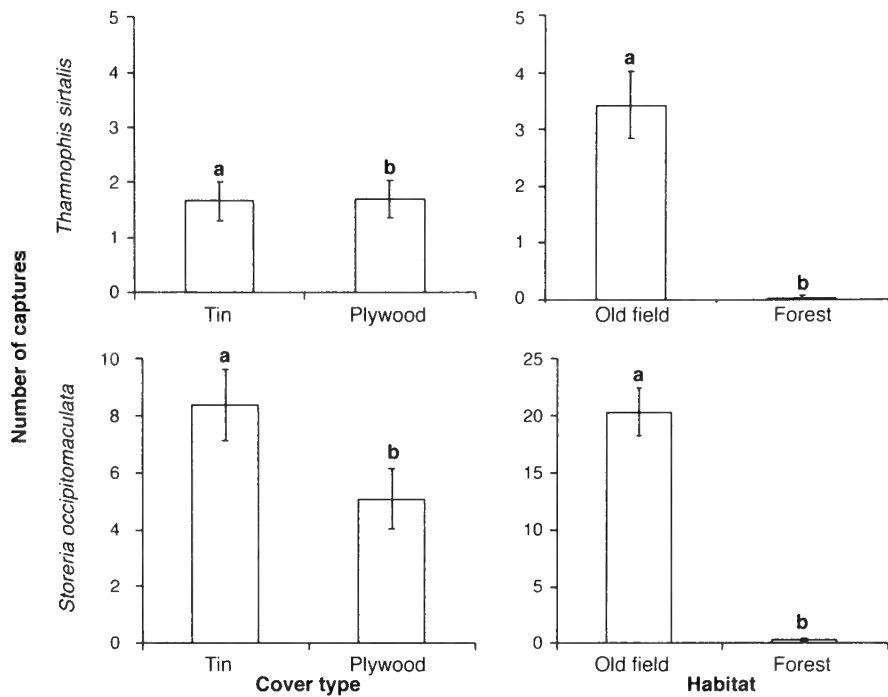


FIGURE 1. Number of captures of Red-bellied Snakes (*Storeria occipitomaculata*; $n = 242$) and Common Gartersnakes (*Thamnophis sirtalis*; $n = 90$) under plywood and tin coverboards in old field and forest in Gatineau Park, Quebec, Canada, 14 May to 16 November 2015. Each bar represents mean daily captures across four study sites. In each graph, means with the same letter are not significantly different, and error bars represent the standard error.

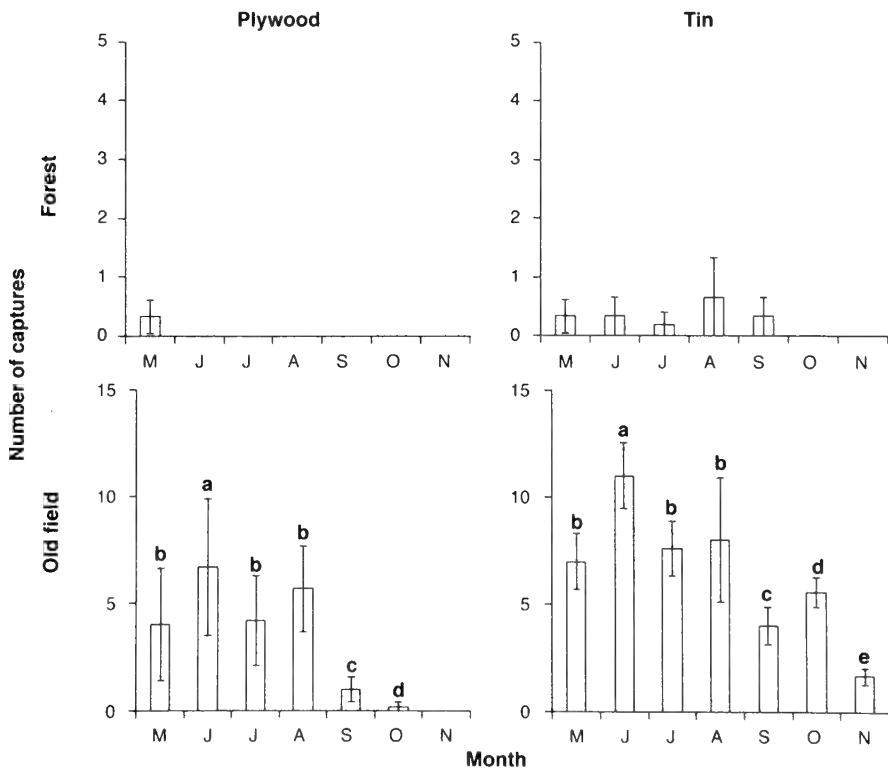


FIGURE 2. Number of captures by month of Red-bellied Snakes (*Storeria occipitomaculata*; $n = 242$) under plywood and tin coverboards in old field and forest in Gatineau Park, Quebec, Canada, 14 May to 16 November 2015. Each bar represents mean monthly captures across all four study sites. In each graph, means with the same letter are not significantly different, and error bars represent the standard error.

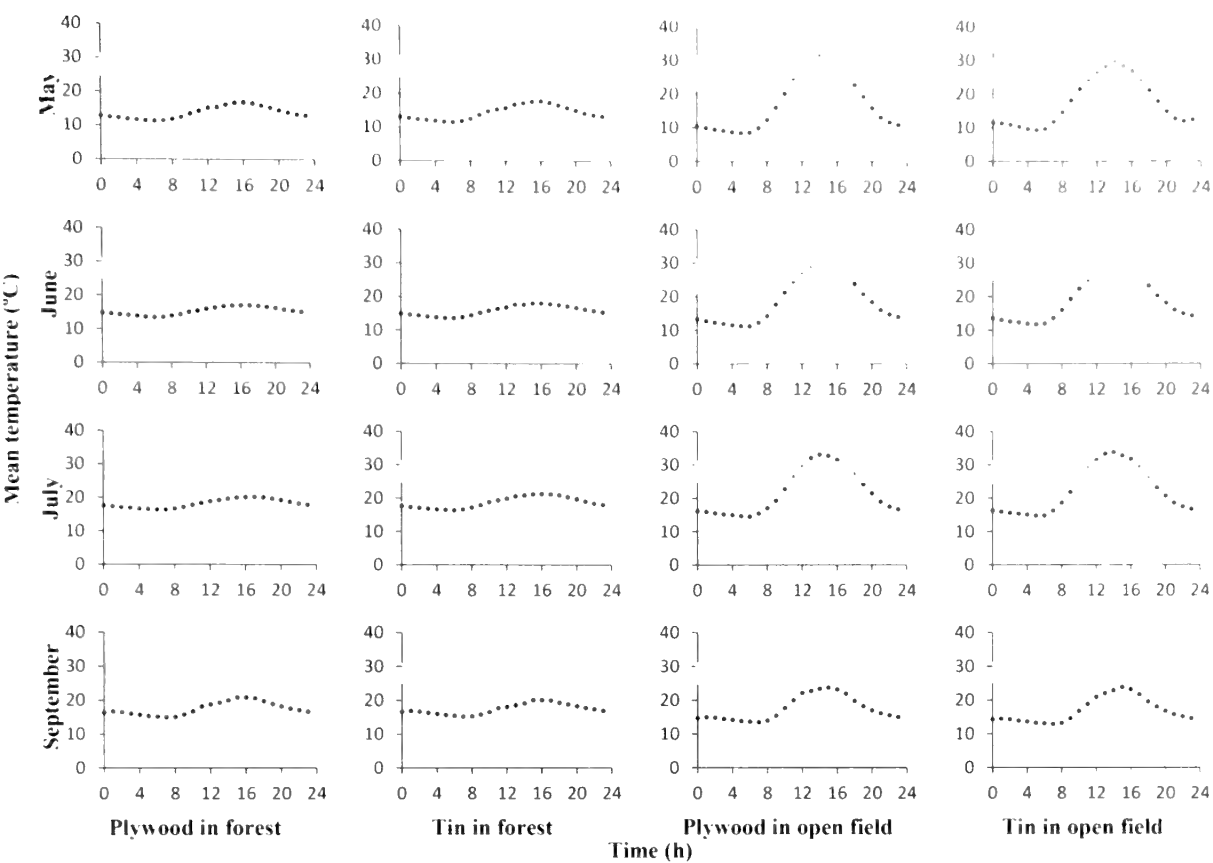


FIGURE 3. Mean temperature profiles under plywood and tin coverboards in old field and forest in Gatineau Park, Quebec, Canada, 2015. The grey rectangle represents the mean preferred temperature of Common Gartersnakes (*Thamnophis sirtalis*): 24.5–30.7°C (Peterson 1987).

Discussion

Both Common Gartersnakes and Red-bellied Snakes strongly preferred old field over forests, a pattern also observed in previous studies of other snakes (Charland and Gregory 1995; Row and Blouin-Demers 2006b; Kapfer *et al.* 2008; Lagory *et al.* 2009; Halliday and Blouin-Demers 2016). Old fields offered significantly higher temperatures than forests, particularly in May, June, and July. These patterns are consistent with the hypothesis that northern snakes are more abundant in open habitats because of their high thermal quality. Halliday and Blouin-Demers (2016) demonstrated that Common Gartersnakes prefer open habitats and that open habitats offer the best thermal conditions and the greatest fitness in terms of reproductive output and growth rate. Similarly, Black Ratsnakes use open habitats to increase fitness (measured by locomotor performance; Blouin-Demers and Weatherhead 2008). It is important to note that, although open habitats are preferred by many snake species, forest can still be important. For example, Eastern Massasauga Rattlesnakes (*Sistrurus catenatus*) prefer forest for hibernation (Harvey and Weatherhead 2006).

Most Common Gartersnakes and Red-bellied Snakes were captured from May to August with a peak in June and July, which corresponds with the highest maximum temperatures. Because body temperature directly affects physiological, reproductive, and ecological performance (Huey 1982), it is likely that the high number of captures during warmer months results from favourable thermal conditions. From May to August, high solar radiation heated the coverboards in old fields rendering them useful for behavioural thermoregulation.

It is worth noting that this study took place in a challenging thermal environment for ectotherms, where thermal quality is expected to be a strong predictor of habitat selection. In more southern and tropical locations, snakes often use forest (Luiselli and Capizzi 1997; Baxley *et al.* 2011; Steen *et al.* 2012), suggesting that thermal quality may not be a strong predictor of habitat selection in warmer areas. In Illinois, a less thermally challenging environment, Black Ratsnakes use forest more and forest edges less than populations of the same species in Ontario (Carfagno and Weatherhead 2006). Similarly, Five-lined Skink (*Plestiodon fasciatus*) uses open habitats in the northern part of its

range (Quirt *et al.* 2006; Brazeau 2016), whereas it is found in forests in the southern part of its range (Watson and Gough 2012). Therefore, although northern populations of species, such as Common Gartersnake and Red-bellied Snake, prefer open habitats because of their thermal needs, southern populations of the same species may prefer different habitats for other reasons, such as prey density (Madsen and Shine 1996; Wasko and Sasa 2012).

Another possible explanation for the preference of northern snakes for open habitats is that coverboards act as refuges reducing predation risk associated with open habitats. Cover serves both as a resting place to avoid detection (Webb and Whiting 2005) and as a refuge for individuals that have been detected in open habitats (Martin and Lopez 2015). In fact, small snakes are found more frequently under cover in open habitats than large snakes, most likely because small snakes use cover as protection from predators (Gregory and Tuttle 2016).

Tin was preferred over plywood coverboards by Red-bellied Snakes, as also observed in some other snakes (Engelstoft and Ovaska 2000; Halliday and Blouin-Demers 2015). Although Engelstoft and Ovaska (2000) believed this was because tin is a better thermal conductor than plywood, we did not detect a significant difference between temperatures under tin and plywood coverboards. Furthermore, Common Gartersnakes did not prefer tin coverboards, but this may be a result of fewer captures (90 Common Gartersnakes versus 242 Red-bellied Snakes) and, thus, less power to detect a preference. The intriguing preference for tin over plywood coverboards in several snakes warrants further study.

In conclusion, Common Gartersnakes and Red-bellied Snakes were more abundant in old fields than in forest, confirming the preference of northern snakes for open habitats, likely because such habitats facilitate behavioural thermoregulation. However, an important caveat must be made: snakes were sampled exclusively with coverboards, and coverboards may be more attractive to snakes in open habitats than in closed habitats. For instance, we showed that coverboards in fields became warmer than coverboards in forest because they received more solar radiation. In fact, coverboards in forest never reached the preferred body temperature range of small northern snakes. Therefore, it is possible that coverboards in fields are more attractive to snakes because of their superior thermal attributes and, thus, are used more than coverboards in forest. If this is the case, the number of captures under coverboards may not be an accurate reflection of the relative density of snakes in the two habitats. This potential bias clearly deserves further study using different sampling methods.

Acknowledgements

We are grateful to William Halliday and James Paterson for their help with analyses. We are indebted to Caroline Gagné of the Nature Conservancy of Canada, to Isabelle Beaudoin-Roy, Catherine Verreault, and Jocelyne Jacob of the National Capital Commission, and to the Natural Sciences and Engineering Research Council of Canada for financial support. We thank Audrey Paquette and Mélanie Routh of the National Capital Commission for providing detailed descriptions of the study sites. We also thank Simon Pelletier, Pierre-André Bernier, and Sylvain Giguère for their help in setting up the coverboards.

Literature Cited

- Baxley, D., G. Lipps, and C. Qualls. 2011. Multiscale habitat selection by black pine snakes (*Pituophis melanoleucus lodingi*) in southern Mississippi. *Herpetologica* 67: 154–166. <https://doi.org/10.1655/HERPETOLOGICA-D-10-00029.1>
- Blouin-Demers, G., and P. Weatherhead. 2001. An experimental test of the link between foraging, habitat selection and thermoregulation in black rat snakes *Elaphe obsoleta obsoleta*. *Journal of Animal Ecology* 70: 1006–1013. <https://doi.org/10.1046/j.0021-8790.2001.00554.x>
- Blouin-Demers, G., and P. Weatherhead. 2008. Habitat use is linked to components of fitness through the temperature-dependence of performance in ratsnakes (*Elaphe obsoleta*). *Israel Journal of Ecology & Evolution* 54: 361–372. <https://doi.org/10.1560/IJEE.54.3-4.361>
- Brattstrom, B. 1965. Body temperatures of reptiles. *American Midland Naturalist* 73: 376–422. <https://doi.org/10.2307/2423461>
- Brazeau, D. J. 2016. Habitat selection in the common five-lined skink near the northern extent of its range. M.Sc. thesis, Lakehead University, Thunder Bay, Ontario, Canada.
- Brown, J. 1984. On the relationship between abundance and distribution of species. *American Naturalist* 124: 255–279. <https://doi.org/10.1086/284267>
- Carfagno, G., and P. Weatherhead. 2006. Intraspecific and interspecific variation in use of forest-edge habitat by snakes. *Canadian Journal of Zoology* 84: 1440–1452. <https://doi.org/10.1139/z06-124>
- Charland, M., and P. Gregory. 1995. Movements and habitat use in gravid and nongravid female garter snakes (Colubridae: *Thamnophis*). *Journal of Zoology* 236: 543–561. <https://doi.org/10.1111/j.1469-7998.1995.tb02731.x>
- Cooper, Jr., W. E., J. H. Van Wyk, and P. le F. N. Mouton. 1999. Incompletely protective refuges: selection and associated defences by a lizard, *Cordylus cordylus* (Squamata: Cordylidae). *Ethology* 105: 687–700. <https://doi.org/10.1046/j.1439-0310.1999.00447.x>
- Dobzhansky, T. 1950. Mendelian populations and their evolution. *American Naturalist* 84: 401–418.
- Engelstoft, C., and K. E. Ovaska. 2000. Artificial cover-objects as a method for sampling snakes (*Contia tenuis* and *Thamnophis* spp.) in British Columbia. *Northwestern Naturalist* 81: 35–43. <https://doi.org/10.2307/3536898>
- Goldsbrough, C. L., R. Shine, and D. F. Hochuli. 2006. Factors affecting retreat-site selection by coppertail skinks (*Ctenotus taeniolatus*) from sandstone outcrops in eastern

- Australia. *Austral Ecology* 31: 326–336. <https://doi.org/10.1111/j.1442-9993.2006.01561.x>
- Grant, B. W., A. D. Tucker, J. E. Lovich, A. M. Mills, P. M. Dixon, and J. Whitfield Gibbons. 1992. The use of coverboards in estimating patterns of reptile and amphibian biodiversity. Pages 379–403 in *Wildlife 2001: Populations*. Edited by D. R. McCullough and R. H. Barrett. Elsevier Applied Science, London, United Kingdom. https://doi.org/10.1007/978-94-011-2868-1_31
- Gregory, P. T., and K. N. Tuttle. 2016. Effects of body size and reproductive state on cover use of five species of temperate-zone natricine snakes. *Herpetologica* 72: 64–72. <http://doi.org/10.1655/HERPETOLOGICA-D-15-00021>
- Halliday, W., and G. Blouin-Demers. 2015. Efficacy of coverboards for sampling small northern snakes. *Herpetology Notes* 8: 309–314.
- Halliday, W. D., and G. Blouin-Demers. 2016. Differential fitness in field and forest explains density-independent habitat selection by gartersnakes. *Oecologia* 181: 841–851. <https://doi.org/10.1007/s00442-016-3605-6>
- Harvey, D. S., and P. J. Weatherhead. 2006. Hibernation site selection by eastern massasauga rattlesnakes (*Sistrurus catenatus catenatus*) near their northern range limit. *Journal of Herpetology* 40: 66–73. <https://doi.org/10.1670/89-05A.1>
- Hecnar, S. J., and D. R. Hecnar. 2011. Microhabitat selection of woody debris by Dekay's brownsnake (*Storeria dekayi*) in a dune habitat in Ontario, Canada. *Journal of Herpetology* 45: 478–483. <https://doi.org/10.1670/10-219.1>
- Houze, Jr., C. M., and C. R. Chandler. 2002. Evaluation of coverboards for sampling terrestrial salamanders in South Georgia. *Journal of Herpetology* 36: 75–81. [https://doi.org/10.1670/0022-1511\(2002\)036\[0075:EOCFST\]2.0.CO;2](https://doi.org/10.1670/0022-1511(2002)036[0075:EOCFST]2.0.CO;2)
- Huey, R. 1982. Temperature, physiology, and the ecology of reptiles. *Biology of the Reptilia* 12: 25–91.
- Huey, R. B., C. R. Peterson, S. J. Arnold, and W. P. Porter. 1989. Hot rocks and not-so-hot rocks: retreat-site selection by garter snakes and its thermal consequences. *Ecology* 70: 931–944. <https://doi.org/10.2307/1941360>
- Hyde, E. J., and T. R. Simons. 2001. Sampling plethodontid salamanders: sources of variability. *Journal of Wildlife Management* 65: 624–632. <https://doi.org/10.2307/3803013>
- Kapfer, J. M., J. R. Coggins, and R. Hay. 2008. Spatial ecology and habitat selection of bullsnakes (*Pituophis catenifer sayi*) at the northern periphery of their geographic range. *Copeia* 2008: 815–826. <https://doi.org/10.1643/CE-07-104>
- Krohmer, R. W. 1989. Body temperature relationships in the lined snake, *Tropidoclonion lineatum*. *Comparative Biochemistry and Physiology Part A: Physiology* 92: 541–543. [https://doi.org/10.1016/0300-9629\(89\)90362-9](https://doi.org/10.1016/0300-9629(89)90362-9)
- Lagory, K. E., L. J. Walston, C. Goulet, R. A. Van Lonkhuyzen, S. Najjar, and C. Andrews. 2009. An examination of scale-dependent resource use by eastern hognose snakes in southcentral New Hampshire. *Journal of Wildlife Management* 73: 1387–1393. <https://doi.org/10.2193/2008-422>
- Luiselli, L., and D. Capizzi. 1997. Influences of area, isolation and habitat features on distribution of snakes in Mediterranean fragmented woodlands. *Biodiversity & Conservation* 6: 1339–1351. <https://doi.org/10.1023/A:1018333512693>
- MacArthur, R. H. 1972. *Geographical Ecology*. Harper and Row, Princeton University Press, Princeton, New Jersey, USA.
- Madsen, T., and R. Shine. 1996. Seasonal migration of predators and prey—a study of pythons and rats in tropical Australia. *Ecology* 77: 149–156. <https://doi.org/10.2307/2265663>
- Martin, J., and P. Lopez. 2015. Hiding time in a refuge. Pages 227–261 in *Escaping from Predators: An Integrative View of Escape Decisions*. Edited by W. F. Cooper, Jr. and D. T. Blumstein. Cambridge University Press, United Kingdom. <https://doi.org/10.1017/CBO9781107447189>
- Martino, J. A., R. G. Poulin, D. L. Parker, and C. M. Somers. 2011. Habitat selection by grassland snakes at northern range limits: implications for conservation. *Journal of Wildlife Management* 76: 759–767. <https://doi.org/10.1002/jwmg.313>
- Peterson, C. R. 1987. Daily variation in the body temperatures of free-ranging garter snakes. *Ecology* 68: 160–169. <https://doi.org/10.2307/1938816>
- Peterson, C. R., A. R. Gibson, and M. E. Dorcas. 1993. Snake thermal ecology: the causes and consequences of body temperature variation. Pages 241–314 in *Snakes: Ecology and Behavior*. Edited by R. A. Seigel and J. Collins. McGraw-Hill, Toronto, Ontario, Canada.
- Quirt, K. C., G. Blouin-Demers, B. J. Howes, and S. C. Loughheed. 2006. Microhabitat selection of five-lined skinks in northern peripheral populations. *Journal of Herpetology* 40: 335–342. [https://doi.org/10.1670/0022-1511\(2006\)40\[335:MSOFSI\]2.0.CO;2](https://doi.org/10.1670/0022-1511(2006)40[335:MSOFSI]2.0.CO;2)
- R Core Team. 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
- Reinert, H. K. 1993. Habitat selection in snakes. Pages 201–240 in *Snakes: Ecology and Behavior*. Edited by R. A. Seigel and J. Collins. McGraw-Hill, Toronto, Ontario, Canada.
- Reinert, H., and W. Kodrich. 1982. Movements and habitat utilization by the massasauga, *Sistrurus catenatus catenatus*. *Journal of Herpetology* 16: 162–171. <https://doi.org/10.2307/1563809>
- Row, J. R., and G. Blouin-Demers. 2006a. Thermal quality influences habitat selection at multiple spatial scales in milksnakes. *Ecoscience* 13: 443–450. [https://doi.org/10.2980/1195-6860\(2006\)13\[443:TQIHS\]2.0.CO;2](https://doi.org/10.2980/1195-6860(2006)13[443:TQIHS]2.0.CO;2)
- Row, J. R., and G. Blouin-Demers. 2006b. Thermal quality influences effectiveness of thermoregulation, habitat use, and behaviour in milk snakes. *Oecologia* 148: 1–11. <https://doi.org/10.1007/s00442-005-0350-7>
- Ryan, T. J., T. Philippi, Y. A. Leiden, M. E. Dorcas, T. B. Wigley, and J. W. Gibbons. 2002. Monitoring herpetofauna in a managed forest landscape: effects of habitat types and census techniques. *Forest Ecology and Management* 167: 83–90. [https://doi.org/10.1016/S0378-1127\(01\)00692-2](https://doi.org/10.1016/S0378-1127(01)00692-2)
- Sagarin, R. D., S. D. Gaines, and B. Gaylord. 2006. Moving beyond assumptions to understand abundance distributions across the ranges of species. *Trends in Ecology & Evolution* 21: 524–530. <https://doi.org/10.1016/j.tree.2006.06.008>
- Steen, D. A., C. J. McClure, J. C. Brock, D. C. Rudolph, J. B. Pierce, J. R. Lee, W. J. Humphries, B. B. Gregory, W. B. Sutton, L. L. Smith, and D. L. Baxley. 2012. Landscape-level influences of terrestrial snake occupancy within the southeastern United States. *Ecological Applications* 22:1084–97. <https://doi.org/10.1890/11-1777.1>
- Wasko, D. K., and M. Sasa. 2012. Food resources influence spatial ecology, habitat selection, and foraging behavior in an ambush-hunting snake (Viperidae: *Bothrops asper*): an experimental study. *Zoology* 115: 179–187. <https://doi.org/10.1016/j.zool.2011.10.001>
- Watson, C. M., and L. Gough. 2012. The role of temperature in determining the distribution and coexistence of three

- species of *Plestiodon*. *Journal of Thermal Biology* 37: 374–379. <http://doi.org/10.1016/j.jtherbio.2012.02.001>
- Webb, J. K., and M. J. Whiting.** 2005. Why don't small snakes bask? Juvenile broad-headed snakes trade thermal benefits for safety. *Oikos* 110: 515–522. <http://doi.org/10.1111/j.0030-1299.2005.13722.x>
- Winne, C. T., J. D. Willson, K. M. Andrews, and R. N. Reed.** 2006. Efficacy of marking snakes with disposable medical cautery units. *Herpetological Review* 37: 52–54.
- Received 9 July 2016
Accepted 30 May 2017

SUPPLEMENTARY MATERIAL:

APPENDIX S1: Detailed descriptions of the study sites, provided by Audrey Paquette and Mélanie Routh under the supervision of Jocelyne Jacob, National Capital Commission, Gatineau Park.

Note

Side to Side Swaying as a Defensive Behaviour in the Dekay's Brownsnake (*Storeria dekayi*)

DAVID L. LEGRÓS

Algonquin Provincial Park, P.O. Box 219, Whitney, Ontario K0J 2M0 Canada; e-mail: david.legros@ontario.ca

LeGros, David L. 2017. Side to side swaying as a defensive behaviour in the Dekay's Brownsnake (*Storeria dekayi*). Canadian Field-Naturalist 131(3): 235–237. <https://doi.org/10.22621/cfn.v131i3.1897>

When discovered by humans, Dekay's Brownsnake (*Storeria dekayi*) exhibits a range of defensive behaviours that are likely used to cope with a variety of potential predators. After being handled, a brownsnake at Rondeau Provincial Park, Ontario, Canada, was observed to coil the anterior portion of its body and to sway the coil from side to side as it attempted to flee. Swaying has rarely been documented in Dekay's Brownsnake and may be a tactic to distract or confuse a visually oriented predator.

Key Words: Dekay's Brownsnake; Northern Brownsnake; *Storeria dekayi*; defensive behaviour; swaying; Rondeau Provincial Park; Ontario

Dekay's Brownsnake (*Storeria dekayi* (Holbrook, 1836)), is a small, terrestrial snake found throughout much of eastern North America, although its Canadian distribution is limited to southern and central Ontario and extreme southwestern Quebec (Cook 1984; Rowell 2012). Dekay's Brownsnake may be common to abundant in appropriate habitat (Catling and Freedman 1980), such as meadows and forest edges, where it preys on invertebrates, primarily terrestrial snails, slugs, and worms (Freedman and Catling 1978; Ernst and Ernst 2003; Rowell 2012; Gray 2014a). The small size of this species makes it vulnerable to predation by a variety of wildlife, including mammals, birds, other snakes, and even arachnids (Bittner 2003; Ernst and Ernst 2003).

When faced with a predator, Dekay's Brownsnake may respond to both visual and tactile stimuli by demonstrating a suite of defensive postures and behaviours (Ernst and Ernst 2003; Gray 2014b, 2015). Here, I present an observation of defensive behaviour that combines the more commonly observed dorso-ventral flattening with swaying of the body, as described by Gray (2014b), in a free-ranging, surface-active Dekay's Brownsnake, near the northern limit of the species' range. Some defensive behaviours may vary geographically or by population (B. S. Gray, personal communication, 2016), with Ontario's Dekay's Brownsnakes possibly being an intergrade between two subspecies: *S. d. dekayi* and *S. d. wrightorum* (Rowell 2012).

On 20 May 2016, at approximately 1800, I encountered an adult female Dekay's Brownsnake, about 25 cm total length, crossing the Marsh Trail at Rondeau Provincial Park, southwestern Ontario (42°17'N, 81°51'W). Although I did not record temperature at the time of the observation, the maximum daily temperature was 16.7°C, and approximately 15.9°C at 1800 (Environment Canada 2016). As I approached the snake, intending to remove it from the trail, it remained still and flat-

tened its body dorso-ventrally. When grasped, the snake voided the contents of its cloaca. I placed the snake back on the trail, fully outstretched, to take photographs. After a minute, it began to exhibit the well documented defensive behaviour (Gray 2014b,c, 2015) of coiling the anterior portion of its body to form a large, open loop flattening its body dorso-ventrally to reveal the checkered pattern on the expanded skin of the coil (Figure 1).

Soon afterward, I observed a novel behaviour: the snake began to move forward while maintaining the defensive position, slowly swaying the coil from side to side, approximately 1 cm to the left and right, slightly raised over the ground. The snake was allowed to escape after photos were taken.

Many small natricine snakes exhibit a great variety of anti-predator responses, often a greater repertoire than some larger snakes (Gray 2015; Gregory 2016). In the case of Dekay's Brownsnake, a wide range of responses to predation attempts has been documented. These include non-intimidating defensive behaviours, such as fleeing, head-hiding, remaining still, and smearing cloacal contents on its own body or on the captor; escalated responses, such as biting, open- and closed-mouth striking; and defensive posturing, such as creating an S-shaped curve with the anterior portion of the body and dorso-ventral flattening of the body, presumably to appear larger (Gray 2015). Defensive reactions of Dekay's Brownsnakes may include a combination of these behaviours and postures (Ernst and Ernst 2003; Rowell 2012; Gray 2014c, 2015). Tactile contact with the animal is required to elicit many defensive responses (Gray 2014b, 2015).

The brownsnake I observed displayed several typical and well-documented responses to discovery (Gray 2014b, 2015). However, my observation of the snake slowly moving forward in an attempt to flee and swaying an anterior coil appears to have not been previously



FIGURE 1. Dekay's Brownsnake (*Storeria dekayi*) exhibiting dorso-ventral flattening and a defensive coil, which was swayed side to side as the snake slowly fled, 20 May 2016, Rondeau Provincial Park, Ontario. Photo: D. LeGros.

reported. Gray (2014b; personal communication, 2016) mentions the swaying behaviour of an exceptionally cold (-0.6°C) Dekay's Brownsnake that was uncoiled and restrained in hand. Snakes that exhibit a variety of responses to potential predators may be limited by suboptimal temperatures to stationary responses, such as gaping, death feigning, and flattening (Keogh and DeSerto 1994; Gerald 2008; Gray 2015). The slow crawl, featuring the defensive S-curve of the Dekay's Brownsnake in my observation may have been related to the moderate ambient temperature (roughly 16°C), as snakes that are warmer may flee from predators faster, limiting their time of exposure to a threat (Gray 2015).

Dekay's Brownsnakes exhibit bimodal seasonal activity; thus, encounters with people peak in spring and autumn and snakes may be observed in the open during the day in these seasons (Rowell 2012; Gray 2014a). Presumably, many snakes tend to avoid open areas and potential exposure to predators; however, they may respond either by moving quickly to reduce exposure time or by moving very slowly to draw minimal attention to themselves (Gregory 2016). Because of the secretive nature of Dekay's Brownsnake, most formal research on this species is conducted by sampling cover objects (Hecnar and Hecnar 2010; Gray 2014a,b,c,

2015). As a result, snakes that are encountered are typically under cover and not active on the surface, allowing few opportunities to study their defensive behaviour.

Small snakes that are actively moving during the day, such as Dekay's Brownsnake, are exposed to many kinds of visual predators that forage in the leaf litter. I speculate that ground-foraging birds might be the predators that elicit the behaviour I observed. Ernst and Ernst (2003) cite American Robin (*Turdus migratorius*) and Brown Thrasher (*Toxostoma rufum*) as confirmed predators of this snake, and Blue Jay (*Cyanocitta cristata*) has also been observed attempting to prey on this species (B. S. Gray, personal communication, 2016). My observation coincided with the end of spring migration of birds through Rondeau Provincial Park, and both American Robins and Brown Thrashers were abundant, both as migrants and residents in late May (cBird 2016; personal observation, 2016). Many birds prefer small or juvenile snakes to large or adult individuals (Bittner 2003), and Dekay's Brownsnake is rather small and inoffensive. Swaying possibly serves to confuse visual predators, such as birds, increasing time for escape. Swaying may also make it more difficult for a predator to strike accurately. Contrary to a swaying tail

display, which diverts attention away from vital organs and body parts (Greene 1997), swaying of the anterior region may draw attention to this vulnerable region, and, thus, the exact function of this display remains unclear. Despite the difficulty of studying the defensive behaviour of free-ranging snakes (Gray 2015; Gregory 2016), opportunistic field observations, such as this one, may contribute to our understanding of such behaviour.

Acknowledgements

I thank the anonymous reviewers who commented on earlier versions of this manuscript, as well as B. S. Gray, Natural History Museum at the Tom Ridge Environmental Center, 301 Peninsula Drive, Erie, Pennsylvania 16505, for communications, thoughtful comments, and suggestions on an earlier draft of this note. Special thanks to Cortney LeGros for assistance with taking photos of the snake.

Literature Cited

- Bittner, T. D.** 2003. Polymorphic clay models of *Thamnophis sirtalis* suggest patterns of avian predation. *Ohio Journal of Science* 103: 62–66.
- Catling, P. M., and B. Freedman.** 1980. Food and feeding of sympatric snakes at Amherstburg, Ontario. *Canadian Field-Naturalist* 94: 28–33. Accessed 6 November 2017. <https://www.biodiversitylibrary.org/item/89247#page/38/mode/lup>.
- Cook, F. R.** 1984. Introduction au reptiles et amphibiens du Canada. National Museum of Natural Sciences, Ottawa, Ontario, Canada. <https://doi.org/10.5962/bhl.title.124171>
- eBird.** 2016. eBird: An online database of bird distribution and abundance. Audubon, New York, and Cornell Lab of Ornithology, Ithaca, New York, USA. Accessed 2 December 2016. <http://ebird.org/ebird/barchart?byr=1900&eyr=2017&bmo=1&emo=12&r=CA-ON-KT>.
- Environment Canada.** 2017. Hourly data report for May 20, 2016 [Erieau, Ontario]. Environment Canada, Ottawa, Ontario, Canada. Accessed 12 October 2017. <https://tinyurl.com/y8z33jzq>.
- Ernst, C. H., and E. M. Ernst.** 2003. Snakes of the United States and Canada. Smithsonian Books, Washington, DC, USA.
- Freedman, W., and P. M. Catling.** 1978. Population size and structure of four sympatric snake species at Amherstburg, Ontario. *Canadian Field-Naturalist* 92: 167–173. Accessed 6 November 2017. <https://www.biodiversitylibrary.org/item/89184#page/181/mode/lup>.
- Gerald, G. W.** 2008. Feign versus flight: influences of temperature, body size and locomotor ability in death feigning neonate snakes. *Animal Behavior* 75: 647–654. <https://doi.org/10.1016/j.anbehav.2007.07.018>
- Gray, B. S.** 2014a. Natural history of the Dekay's Brownsnake, *Storeria dekayi* (Holbrook, 1836) at a site in north-western Pennsylvania. *Journal of North American Herpetology* 2014: 28–39.
- Gray, B. S.** 2014b. *Storeria dekayi* (Dekay's Brownsnake). Cold tolerance. *Herpetological Review* 45: 148.
- Gray, B. S.** 2014c. The defensive behaviors of Dekay's Brownsnake, *Storeria dekayi*: an illustrated review of a diverse repertoire. *Collinsorum* 3: 20–27.
- Gray, B. S.** 2015. A study of the defensive behaviors of free-ranging Dekay's Brownsnakes, *Storeria dekayi* (Holbrook, 1836). *Journal of North American Herpetology* 2015: 43–52.
- Greene, H. W.** 1997. Snakes: Evolution of Mystery in Nature. University of California Press, Berkeley, California, USA.
- Gregory, P. T.** 2016. Responses of natricine snakes to predatory threat: a mini-review and research prospectus. *Journal of Herpetology* 50: 183–195. <https://doi.org/10.1670/15-103>
- Hecnar, S. J., and D. R. Hecnar.** 2010. Microhabitat selection of woody debris by Dekay's Brownsnake (*Storeria dekayi*) in a dune habitat in Ontario, Canada. *Journal of Herpetology* 45: 478–483. <https://doi.org/10.1670/10-219.1>
- Keogh, J. S., and F. P. DeSerto.** 1994. Temperature dependent defensive behavior in three species of North American colubrid snakes. *Journal of Herpetology* 28: 258–261. <https://doi.org/10.2307/1564633>
- Rowell, J. C.** 2012. The Snakes of Ontario: Natural History, Distribution, and Status. J. C. Rowell, Toronto, Ontario, Canada.

Received 20 December 2016

Accepted 20 June 2017

Psychrotolerant Microfungi Associated with Deer Mice (*Peromyscus maniculatus*) in a White-nose Syndrome Positive Bat Hibernaculum in Eastern Canada

KAREN J. VANDERWOLF^{1, 2, 3, 4}, DAVID MALLOCH¹, and DONALD F. MCALPINE¹

¹Department of Natural Science, New Brunswick Museum, 277 Douglas Avenue, Saint John, New Brunswick E2K 1E5 Canada

²Canadian Wildlife Federation, 350 Michael Cowpland Drive, Kanata, Ontario K2M 2W1 Canada

³Current address: Department of Pathobiological Sciences, University of Wisconsin, 1656 Linden Drive, Madison, Wisconsin 53706 USA

⁴Corresponding author: kjvanderw@gmail.com

Vanderwolf, Karen J., David Malloch, and Donald F. McAlpine. 2017. Psychrotolerant microfungi associated with Deer Mice (*Peromyscus maniculatus*) in a white-nose syndrome positive bat hibernaculum in eastern Canada. *Canadian Field-Naturalist* 131(3): 238–245. <https://doi.org/10.22621/cfn.v131i3.1906>

With the exception of recent work on bats, no reports on the fungi present on live mammals in underground habitats have been published. We cultured psychrotolerant fungi from the external surface and faeces of live Deer Mice (*Peromyscus maniculatus*), and from the intestinal contents of a single freshly killed *P. maniculatus*, overwintering in a white-nose syndrome positive bat hibernaculum and from adjacent summer forest in eastern Canada. A low diversity of psychrotolerant fungi was cultured from *P. maniculatus* compared with that found in previous studies of the mycoflora of bats and arthropods occupying bat hibernacula in the region. Although the grooming habits of *P. maniculatus* may reduce the accumulation of a diverse psychrotolerant fungal assemblage on their external surface, we demonstrate that active euthermic mammals in underground habitats can carry viable spores of psychrotolerant fungi, both externally and internally. Small rodents using cave habitats may also play a role in dispersing psychrotolerant fungi between caves and suitable low-temperature habitats (i.e., burrows) in adjacent forest.

Key Words: *Pseudogymnoascus destructans*; Deer Mouse; *Peromyscus maniculatus*; cave fungi; cave mycota; cold-tolerant fungi; fungal dispersal; white-nose syndrome

Introduction

Mammals introduce organic matter, including fungal spores, into underground habitats, where nesting material, food caches, scat, carcasses, and shed hair and skin serve as substrates for various fungi (Nelson and Smith 1976; Jurado *et al.* 2010). The introduction to North American caves and cave-like habitats (i.e., mines; hereafter we include such habitats under the generic term “caves”) of the psychrotolerant (cold-tolerant) fungus *Pseudogymnoascus destructans*, causative agent of the lethal bat disease, white-nose syndrome (WNS; Lorch *et al.* 2011), has prompted increased interest in the mycology of caves. However, with the exception of recent work focusing on bats (Johnson *et al.* 2013; Vanderwolf *et al.* 2013; 2016a; Lorch *et al.* 2015), no reports on the fungi present on live mammals in caves have been published. In addition, the literature on how psychrotolerant fungi might be dispersed from cave habitats is limited (Stephenson *et al.* 2007; Vanderwolf *et al.* 2016a,b).

Deer Mice (*Peromyscus maniculatus* Wagner, 1845) are a common and widespread North American small rodent that may reside in small numbers in caves, where available, during the winter (Trevor-Deutsch 1973). During the warmer months, this species disperses into surrounding woodland, staying relatively close to cave entrances in spring and early summer and ranging farther

afield in late summer (Fenton 1970; Trevor-Deutsch 1973). Here we report on psychrotolerant fungi associated with overwintering *P. maniculatus* using cave habitat in eastern Canada, where overwintering bat populations were severely reduced after the 2011 arrival of the fungus *Pseudogymnoascus destructans* to the area (McAlpine *et al.* 2011). As a comparison, during the summer months, we also sampled fungi on mice from forest adjacent to this cave habitat.

Methods

Winter Sampling

Peromyscus maniculatus were live-trapped in Dorchester Mine, an abandoned copper mine and bat hibernaculum near Sackville, New Brunswick, 11–14 March 2014 (42 trap nights). Two trap sizes were used: 5.1 × 6.4 × 16.5 cm and 7.7 × 8.9 × 22.9 cm (H. B. Sherman Traps, Inc., Tallahassee, Florida, USA). All traps were soaked in fungicide and rinsed prior to sampling. Traps were baited with a mixture of peanut butter and oats, furnished with cotton nesting material, checked daily, and re-baited as required. Traps were placed on the floor and on ledges along the walls adjacent to a mouse nest (1–2 m above the floor; Figure 1A), approximately 45–80 m from the mine entrance. The temperature in Dorchester Mine was measured using iButtons (model DS1920-F5, Maxim Integrated Products Inc., Sunny-

vale, California, USA) in the manner of Vanderwolf *et al.* (2012).

Each trapped mouse was transferred to a fresh plastic bag for swabbing by inverting the trap over the bag. Two swabs per mouse were taken using a new, sterile, dry, cotton-tipped applicator for each swab. The swabs were rubbed over the fur both dorsally and ventrally. After swabbing, the applicator was immediately streaked across the medium surface in a petri plate. Three diluting streaks were completed in the mine within 1 h of the initial streak, after which plates were sealed *in situ* with parafilm (Pechiney Plastic Packaging, Chicago, Illinois, USA). Two media types were inoculated for each mouse: dextrose peptone yeast extract agar (DPYA) and Sabouraud dextrose agar (SDA), both of which were infused with the antibiotics chlortetracycline (30 mg/L) and streptomycin (30 mg/L). Mice were not directly handled or marked during any part of the procedure and were immediately released after sampling. One mouse was removed from the mine after swabbing of its external surface (New Brunswick Museum specimen 12946), euthanized using isoflurane, and the contents of its stomach, small intestine, and large intestine

were spread on separate petri plates containing DPYA medium with no dilution.

Faeces produced by mice held in bags were transported to the lab for processing. Faeces (< 3 pellets per mouse) were suspended in 100 mL of autoclaved water and vigorously shaken for 10 minutes. The sample was then serially diluted five times, with 10 mL of each successive solution mixed with 90 mL of water. For each of the five dilutions, plus the undiluted sample, 10 mL were spread over the surface of separate petri plates containing hardened DPYA medium.

Summer Sampling

On the night of 27 August 2014, mice were trapped with live traps (100 trap nights) baited with bird seed adjacent to the entrance of Dorchester Mine. All traps were soaked in fungicide and rinsed the day before use. Mice were processed using the methods described above, except that faeces and intestinal contents were not collected. Three mice were swabbed twice, with one swab inoculated on DPYA medium and the other on SDA medium. For all other mice, only one swab was taken and inoculated on DPYA medium because of contamination issues with the SDA medium.

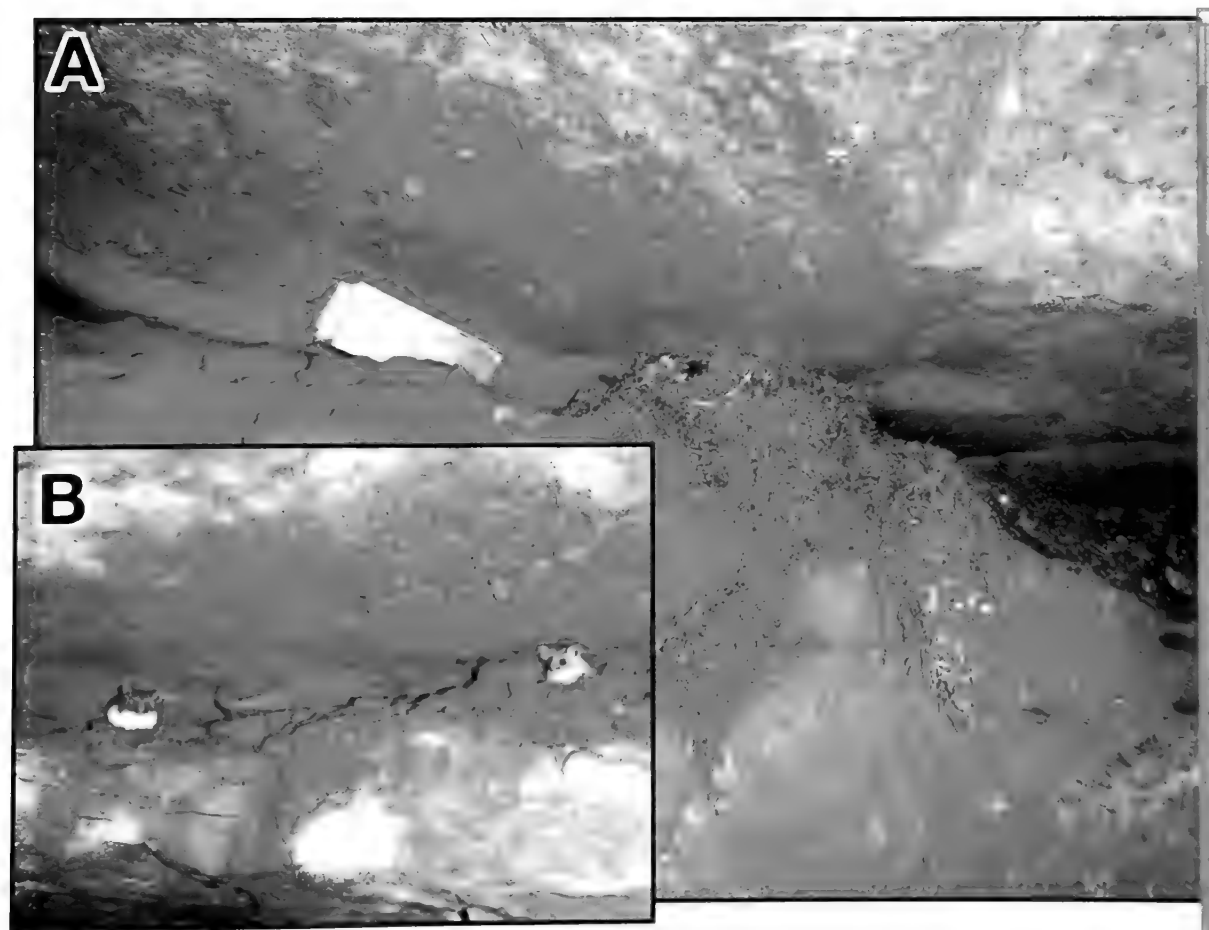


FIGURE 1. A. Deer Mouse (*Peromyscus maniculatus*) nesting material (a source and substrate for fungal spores) and a live trap in place on a wall ledge in Dorchester Mine near Sackville, New Brunswick. B. In winter, *P. maniculatus* were active in the dark zone on wall ledges and the floor of the mine. Photos: K. J. Vanderwolf.

Fungal Culturing and Data Analysis

In the laboratory, samples were incubated, inverted, in the dark at 7°C in a low-temperature incubator (Model 2015, VWR International, Mississauga, Ontario, Canada) to approximate the subterranean environment and target psychrotolerant fungi. Samples were monitored over four months until either no new cultures had appeared for three weeks, or the plate had become overgrown with hyphae. Once fungi began growing on the plates, each distinct colony was subcultured to a new plate. DPYA without oxgall and sodium propionate was used for maintaining pure cultures (Figure 2). Identifications were carried out by comparing the micro- and macro-morphological characteristics of the microfungi to those traits appearing in the taxonomic literature and compendia (Domsch *et al.* 2007; Seifert *et al.* 2011) and by comparing isolates to a reference collection of fungi assembled from previous studies in underground habitats in the region, which were identified using a mix of morphological and molecular methods (Vanderwolf *et al.* 2013, 2016a,b). Permanent desiccant-dried vouchers of the collected fungi are deposited in the New Brunswick Museum mycological collection (NBM numbers F-05152–05155, 05161, 05163–05169, 05246–05256, 05359, 05364–05370, 05394–05400, 05521, 05626).

The numbers of fungal taxa per mouse were not normally distributed and subsequently were square-root transformed. A two-sample *t* test was used to compare the number of fungal taxa per mouse for winter mice versus summer mice using Minitab software (Minitab Inc., Pennsylvania State University, Pennsylvania, USA).

Results

Winter Sampling

Six *P. maniculatus* were captured (two per night) during three days of sampling in Dorchester Mine. Nine fungal taxa and one sterile morph were cultured from the fur of mice sampled in the mine, with a mean of 2.83 fungal taxa per individual (standard deviation [SD] 0.75, range 2–4, *n* = 6 mice). The second swab contributed 0.67 fungal taxa (SD 0.82, range 0–2) that were not detected with the first swab. The most common fungal taxa were *Pseudogymnoascus pannorum sensu lato* (100% of mice; this fungal taxon is polyphyletic, S. Hambleton, personal communication to K.J.V.) and *Penicillium* spp. (50%), while all other taxa were isolated from a single mouse each (Table 1).

Twelve fungal taxa and multiple sterile morphs were isolated from faeces collected from four mice, with a mean of 6.0 fungal taxa per individual (SD 2.83). Two mice did not produce scat before release. The most common fungal taxa cultured from feces were *Mucor* spp. (100% of mice, *n* = 4), *Pseudogymnoascus pannorum sensu lato* (75%), *Penicillium* spp. (75%), *Cephalotrichum stemonitis* (50%), *Thelebolus crustaceus* (50%), and *Leuconeurospora capsici* (50%), while all other taxa were isolated from a single mouse each

(Table 1). Most fungal taxa were obtained from the undiluted sample and the first dilution; the fifth dilution produced no cultures. Seven fungal taxa plus one sterile morph were isolated from mouse gut contents.

The mean temperature in Dorchester Mine during the sampling period, March 2014, was −0.98°C (SD 1.24) in the twilight zone and 6.63°C (SD 0.00) in the dark zone. The twilight zone ibutton was located 3 m inside the entrance. The mean temperature outside the mine, approximately 20 m from the entrance and above snow cover, was −2.49°C (SD 5.31). Mice were generally observed on wall ledges and the floor deeper in the mine (Figure 1B) where air temperatures were warmer, and where they were subsequently captured.

Summer Sampling

Twenty-two fungal taxa plus five sterile morphs were cultured from 15 mice, with a mean of 4.87 fungal taxa per mouse (SD 2.13, range 2–8). Female mice (*n* = 8) carried a mean of 4.75 (SD 2.31) fungal taxa and males (*n* = 5) carried 4.6 (SD 2.30). Two mice escaped before sex was determined. The second swab contributed two fungal taxa (SD 2, range 0–4, *n* = 3 mice) that were not detected with the first swab. The most common fungal taxa were *Mucor* sp. (87% of mice), *Penicillium* sp. (87%), *Cladosporium* sp. (80%), *Pseudogymnoascus pannorum sensu lato* (47%), *Scopulariopsis* sp. (20%), *Thysanophora* sp. (20%), *Alternaria* sp. (13%), and *Microascus* sp. (13%), while all other taxa were isolated from a single mouse each (Table 1). Summer mice captured outside the cave carried a significantly higher number of fungal taxa per individual than winter mice sampled inside the cave ($t_{1,18} = -2.48$, $P = 0.024$). The mean temperature in Dorchester Mine during August 2014 was 13.65°C (SD 0.76) in the twilight zone and 6.59°C (SD 0.00) in the dark zone. The mean temperature outside of the mine, approximately 20 m from the entrance, was 18.12°C (SD 4.21).

Discussion

Mice sampled during our study carried few fungi capable of growing at typical eastern Canadian dark zone cave temperatures, although summer mice carried a higher diversity of psychrotolerant fungi compared with mice swabbed during the winter. The psychrophilic *Pseudogymnoascus destructans* was not detected on mice, but isolates of a closely related species complex, *Pseudogymnoascus pannorum sensu lato*, was cultured from all mice sampled during the winter and on half the mice sampled during the summer. Although only two bats (either Little Brown Myotis [*Myotis lucifugus*] or Northern Long-eared Myotis [*M. septentrionalis*]) were present in Dorchester Mine during the winter 2014 sampling period, viable *P. destructans* was present and was cultured from both walls (Vanderwolf *et al.* 2016c) and arthropods (Vanderwolf *et al.* 2016b) in the mine.

Pseudogymnoascus pannorum is commonly found on various substrates in caves, including hibernating

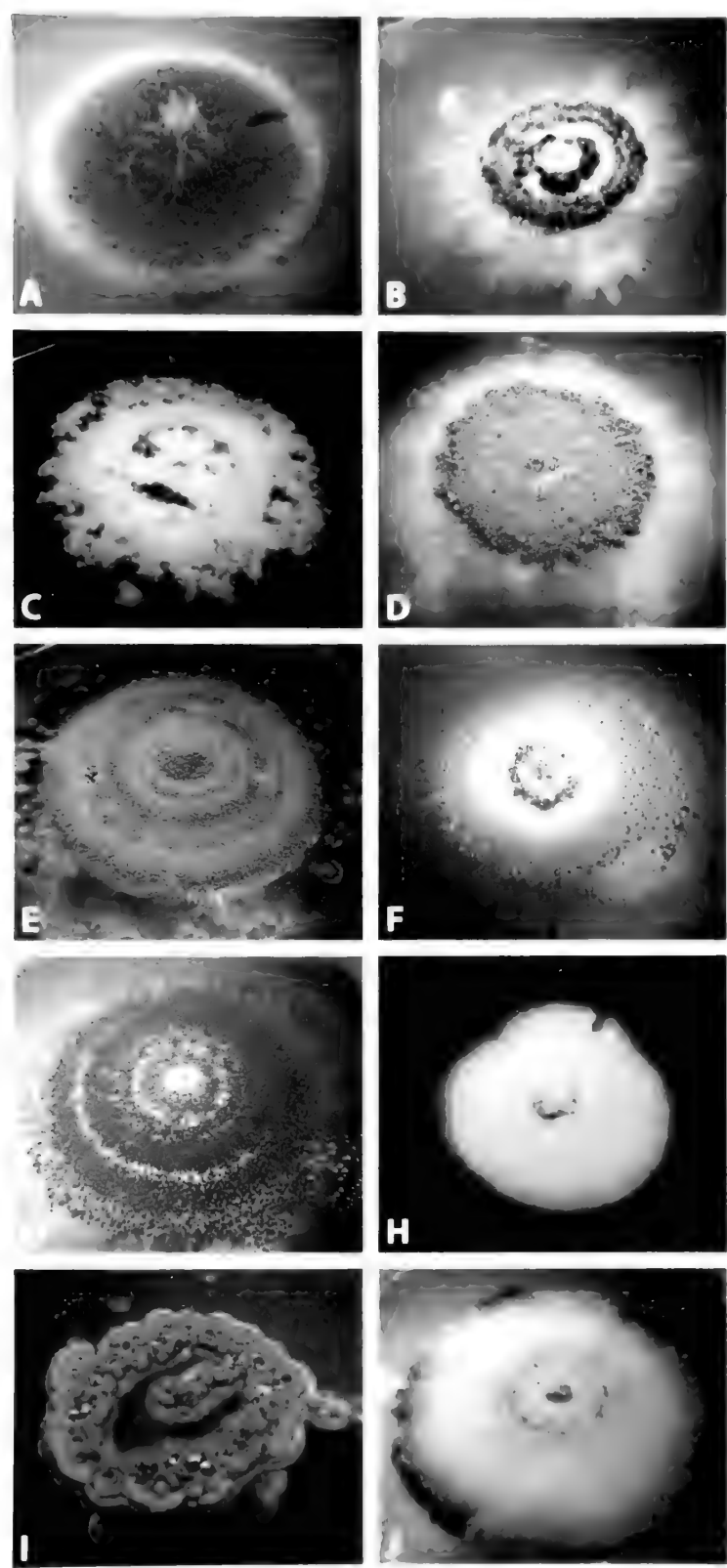


FIGURE 2. Representative psychotolerant fungi in pure culture from the winter (W) and summer (S) fur (FU), faeces (FF), and gut contents (GC) of Deer Mice (*Peromyscus maniculatus*) associated with a white-nose syndrome positive bat hibernaculum in eastern Canada. All cultures on DPYA without oxgall and sodium propionate. A. *Alternaria* sp. (S-FU); B. *Arthrinium phacospermum* (S-FU); C. *Arthoderma silverae* (W-FU, W-GC); D. *Microascus caviariformis* (W-FU, W-FF, W-GC); E. *Oidiodendron* cf. state of *Myxotrichium emodense* (S-FU); F. *Penicillium thomii* (S-FU); G. *Pseudogymnoascus roseus* (W-FE); H. *Scopulariopsis candida* (S-FU); I. *Talaromyces* sp. (W-FU); J. *Thysanophora canadensis* (S-FU). Photos: K. J. Vanderwolf.

TABLE 1. Psychrotolerant fungi cultured from the external surface of Deer Mice (*Peromyscus maniculatus*) captured inside a bat hibernaculum in winter 2014 and outside adjacent to the hibernaculum entrance in summer 2014, New Brunswick, Canada.

Fungus	Winter (no. mice)			Summer (no. mice)
	Fur (n = 6)	Faeces (n = 4)	Gut contents (n = 1)	Fur (n = 15)
ASCOMYCOTA				
<i>Acremonium</i> sp.	0	0	0	1
<i>Alternaria</i> sp.	0	0	0	2
<i>Arthrinium phaeospermum</i> (Corda) M.B. Ellis	0	1	0	1
<i>Arthroderma silverae</i> Currah, S.P. Abbott & Sigler	1	0	1	0
<i>Cephalotrichum stemoniis</i> (Pers.) Link	0	2	0	0
<i>Cladosporium</i> sp.	0	0	0	12
<i>Leuconeurospora capsici</i> (J. F. H. Beyma) Malloch, Sigler & Hambleton	0	2	0	0
<i>Leuconeurospora polypaeciloides</i> Malloch, Sigler and Hambleton	0	0	0	1
<i>Microascus</i> sp.	0	1	1	2
<i>Microascus caviariformis</i> Malloch & Hubart	1	1	1	0
<i>Myxotrichum</i> sp.	0	0	0	1
<i>Oidiodendron</i> cf. <i>state of Myxotrichum emodense</i>	0	0	0	1
<i>Oidiodendron</i> cf. <i>hughesii</i> , cf. <i>myxotrichoides</i>	0	0	0	1
<i>Paecilomyces</i> sp.	1	0	0	0
<i>Penicillium</i> sp.	3	3	1	13
<i>Penicillium thomii</i> Maire	0	0	0	1
<i>Pseudogymnoascus pannorum</i> <i>sensu lato</i> (Link) Minnis & D.L. Lindner	6	3	1	7
<i>Pseudogymnoascus roseus</i> Rallo	0	1	0	0
<i>Sarcinomyces</i> sp.	0	0	0	1
<i>Scopulariopsis</i> sp.	1	0	0	1
<i>Scopulariopsis candida</i> Vuill.	0	0	0	2
<i>Talaromyces</i> sp.	1	0	0	0
<i>Thelebolus</i> sp.	0	1	0	0
<i>Thelebolus crustaceus</i> (Fuckel) Kimbr	0	2	0	0
<i>Thysanophora canadensis</i> Stolk & Hennebert	0	0	0	2
<i>Thysanophora penicillioides</i> (Roum.) W. B. Kendr.	0	0	0	2
<i>Trichoderma</i> sp.	0	0	0	1
<i>Trichophyton</i> sp.	0	0	1	0
BASIDIOMYCOTA				
Unidentified Basidiomycete	0	0	0	1
<i>Trichosporon</i> sp.	0	1	0	0
ZYGOMYCOTA				
<i>Mortierella</i> sp.	1	0	0	1
<i>Mucor</i> sp.	1	4	1	13
<i>Umbelopsis isabellina</i> (Oudem.) W. Gams	0	0	0	1
STERILE MORPH	1	1	1	5

bats (Johnson *et al.* 2013; Vanderwolf *et al.* 2013), and has been isolated from the fur of wild voles, shrews, mice, and rabbits outside caves (Hubalek *et al.* 1979; Chabasse 1988), as well as scat from Arctic Ground Squirrel (*Spermophilus parryii*; Kobayasi *et al.* 1967). *Pseudogymnoascus pannorum* appears to be a common component of the mycobiome of mammalian fur. However, *P. pannorum* is polyphyletic and the resolution of the species complex may reveal different ecological patterns.

Outside caves, the fungal diversity detected on mammals has generally been low. For example, the number of fungal isolates per Persian Squirrel (*Sciurus anom-*

alus; *n* = 60) varied from 0 to 4 (mean 2.6, SD 0.83) with 23 fungal species from 17 genera isolated overall (Rostami *et al.* 2010). Sierra *et al.* (2000) studied fungi on the fur of 85 Domestic Cats (*Felis catus*) and found the number of fungal genera per cat varied from 1 to 9 (mean 3.2). Dermatophytes, such as *Arthroderma benhamiae*, *A. quadrifidum*, *A. persicolor*, and *Chrysosporium* sp. have previously been isolated from *P. maniculatus* fur (Knudtson and Robertstad 1970; Hubalek 2000).

A greater diversity of fungi was cultured from mouse faeces than mouse fur and, paired with fungi cultured from mouse intestinal contents, demonstrate that mice

are capable of transporting viable spores of psychrotolerant fungi internally. These spores may be acquired during feeding and grooming, as five of the fungal genera cultured from faeces were also found on fur. Although faeces collected from the traps may have acquired spores from the environment, Kohl *et al.* (2015) found no significant difference in the microbiome between Desert Woodrat (*Neotoma lepida*) faeces collected aseptically and faeces collected from live traps.

Macrofungi and mycorrhizal fungi are part of the omnivorous diet of *P. maniculatus*, and viable spores of these fungi are frequently detected in their faeces and stomach contents outside caves (Maser and Maser 1987; Pyare and Longland, 2001; Frank *et al.* 2006; D'Avila *et al.* 2007; Meyer *et al.* 2015). It is thought that *P. maniculatus* and other rodents play a role in dispersing fungal spores across the landscape, which is of particular importance with regard to mycorrhizal inoculum (Maser and Maser 1987; Pyare and Longland 2001; Frank *et al.* 2006; D'Avila *et al.* 2007; Meyer *et al.* 2015). However, mice are unlikely to transport fungal spores great distances internally, as Cork and Kenagy (1989) found that the mean retention time of *Elaphomyces granulatus* spores was 12.0 h (standard error 2.4) in *P. maniculatus*.

Nevertheless, evidence suggests that mice opportunistically feed on fungi growing in caves, such as those growing on live and dead bats, decaying leaf litter, and woody debris, or consume spores concomitant with other cave food sources such as arthropods (Peck 1988) and bats (Trevor-Deutsch 1973). Therefore, mice likely play a role in fungal dispersal in underground environments. For example, we observed *Microascus caviariformis* growing in Dorchester Mine, and we subsequently isolated viable spores of this fungus from mouse faeces and from the gut contents. This fungus has rarely been isolated, and never outside caves (Malloch and Hubart 1987; Vanderwolf *et al.* 2013, 2016a).

It is noteworthy that a full 33% of the summer isolates from mice were members of the genus *Microascus*, including related asexual anamorphs assigned to *Scopulariosis* spp. Species of *Microascus* lack the forcible discharge of ascospores common to most ascomycetes and occur in habitats where access to freely flowing air currents is limited. For species of *Microascus*, such habitats include stored grains, soil, dung, and caves (Barron 1961; Vanderwolf *et al.* 2013; Sandoval-Denis *et al.* 2016).

Once *P. maniculatus* leave caves in the spring and disperse into the outside environment (Trevor-Deutsch 1973), they may carry spores of psychrotolerant fungi with them, both internally and externally, to woodland burrow systems. Winter and summer burrow temperatures of *Peromyscus* spp. across a diversity of habitats in North America fall within the range of temperatures at which psychrotolerant fungi will grow, e.g., mean of 10–15°C during summer and 0–6°C during winter in British Columbia, depending on habitat (Hayward

1965). Burrow microclimate may have contributed to the diversity of psychrotolerant fungi we cultured from the fur of mice during the summer.

Several of the fungal genera we isolated from faeces are coprophilous, such as *Cephalotrichum stemonitis*, *Thelebolus* spp., and *Arthroderma silverae* (Currah *et al.* 1996; Domsch *et al.* 2007). Other fungal taxa, especially those we isolated from mice during the summer, such as *Alternaria* spp., *Arthrinium phacospermum*, and *Thysanophora* spp., are often associated with plants (Domsch *et al.* 2007). Genera such as *Mucor*, *Cladosporium*, and *Penicillium* are ubiquitous in the outside environment (Domsch *et al.* 2007) and were more commonly isolated from mice sampled outside the mine than inside.

The relatively low psychrotolerant fungal diversity found on mice during this study is in marked contrast to the diverse fungal assemblage isolated from bats hibernating in caves in the region (Vanderwolf *et al.* 2013, 2016a) and even arthropods at the same site (Vanderwolf *et al.* 2016b). For example, using similar methods, a mean of 8.3 (SD 3.2) fungal taxa per individual were cultured from Harvestmen (*Nelima elegans*; $n = 9$) overwintering in Dorchester Mine.

Peromyscus maniculatus remain active throughout the winter and hence do not undergo a drop in body temperature, unlike hibernating bats. This may decrease the diversity of psychrotolerant fungi on the external surface of *Peromyscus*. Perhaps more important, rodents are effective groomers (Murray 1961; Hallman *et al.* 1993), and *P. maniculatus* overwintering in caves are likely to groom more frequently than hibernating bats. Mammals that regularly groom are able to limit ectoparasites (Murray 1961) and may also be able to limit the mycobiome they carry on their fur, including dermatophytes and psychrotolerant fungi.

Although the sample size of mice available to us was small, this study demonstrates that euthermic mammals occupying caves can carry a variety of viable spores of psychrotolerant fungi, both externally and internally. Small rodents using cave habitats may also play a role in dispersing psychrotolerant fungi between caves and suitable low-temperature habitats (i.e., burrows) in adjacent forest.

Acknowledgements

We thank John Klymko and Sarah Robinson for assisting with winter fieldwork and S. Hambleton (Agriculture Canada, Ottawa, Ontario, Canada) for discussions on fungal taxonomy. Howie Huynh kindly assisted with summer fieldwork. Research funding was provided by the New Brunswick Wildlife Trust Fund, Crabtree Foundation, New Brunswick Environmental Trust Fund, New Brunswick Department of Natural Resources, and Parks Canada. We also thank the Department of Energy and Resource Development for approving our request to euthanize a single Deer Mouse and to live-trap more generally in Dorchester Mine.

Literature Cited

- Barron, G. L., R. F. Cain, and J. C. Gilman.** 1961. The genus *Microascus*. Canadian Journal of Botany 39: 1609–1631. <https://doi.org/10.1139/b61-143>
- Chabasse, D.** 1988. Taxonomic study of keratinophilic fungi isolated from soil and some mammals in France. Mycopathologia 101: 133–140. <https://doi.org/10.1007/BF00437030>
- Cork, S. J., and G. J. Kenagy.** 1989. Rates of gut passage and retention of hypogeous fungal spores in two forest dwelling rodents. Journal of Mammalogy 70: 512–519. <https://doi.org/10.2307/1381423>
- Currah, R. S., S. P. Abbott, and L. Sigler.** 1996. *Arthroderma silverae* sp. nov. and *Chrysosporium vollenarense*, keratinophilic fungi from arctic and montane habitats. Mycological Research 100: 195–198. [https://doi.org/10.1016/s0953-7562\(96\)80121-3](https://doi.org/10.1016/s0953-7562(96)80121-3)
- D'Alva, T., C. Lara, A. Estrada-Torres, and C. Castillo-Guevara.** 2007. Digestive responses of two omnivorous rodents (*Peromyscus maniculatus* and *P. alstoni*) feeding on epigeous fungus (*Russula occidentalis*). Journal of Comparative Physiology B 177: 707–712. <https://doi.org/10.1007/s00360-007-0188-x>
- Domsch, K. H., W. Gams, and T.-H. Anderson.** 2007. Compendium of Soil Fungi. Second edition. IHW-Verlag, Berlin, Germany.
- Fenton, M. B.** 1970. Population studies of *Myotis lucifugus* (Chiroptera: Vespertilionidae) in Ontario. Life sciences contribution 77. Royal Ontario Museum, Toronto, Ontario, Canada.
- Frank, J. L., S. Barry, and D. Southworth.** 2006. Mammal mycophagy and dispersal of mycorrhizal inoculum in Oregon white oak woodlands. Northwest Science 80: 264–273.
- Hallman, T. M., L. C. Adams, D. J. Mullins, and J. R. Tester.** 1993. Duration of effectiveness of fluorescent pigment when tracking small mammals. Canadian Field-Naturalist 107: 370–372. Accessed 23 December 2017. <https://www.biodiversitylibrary.org/item/108204#page/386/mode/1up>.
- Hayward, J. S.** 1965. Microclimate temperature and its adaptive significance in six geographical races of *Peromyscus*. Canadian Journal of Zoology 43: 341–350. <https://doi.org/10.1139/z65-033>
- Hubalek, Z.** 2000. Keratinophilic fungi associated with free-living mammals and birds. Revista Iberoamericana de Micología 17: 93–103.
- Hubalek, Z., B. Rosický, and M. Otčenasek.** 1979. Fungi on the hair of small wild mammals in Czechoslovakia and Yugoslavia. Ceska Mykologie 33: 81–93.
- Johnson, L. J. A. N., A. N. Miller, R. A. McCleery, R. McClanahan, J. A. Kath, S. Lueschow, and A. Porras-Alfaro.** 2013. Psychrophilic and psychrotolerant fungi on bats and the presence of *Geomyces* spp. on bat wings prior to the arrival of white nose syndrome. Applied Environmental Microbiology 79: 5465. <https://doi.org/10.1128/AEM.01429-13>
- Jurado, V., E. Porca, S. Cuezva, A. Fernández-Cortés, S. Sanchez-Moral, and C. Saiz-Jimenez.** 2010. Fungal outbreak in a show cave. Science of the Total Environment 408: 3632–3638. <https://doi.org/10.1016/j.scitotenv.2010.04.057>
- Knudtson, W. U., and G. W. Robertstad.** 1970. The isolation of keratinophilic fungi from soil and wild animals in South Dakota. Mycopathologia et Mycologia Applicata 40: 309–323. <https://doi.org/10.1007/BF02051784>
- Kobayasi, Y., N. Hiratsuka, R. P. Korf, K. Tubaki, K. Aoshima, M. Soneda, and J. Sugiyama.** 1967. Mycological studies of the Alaskan Arctic. Annual Report, Institute Fermentation, Osaka 3: 1–138.
- Kohl, K. D., K. Luong, and M. D. Dearing.** 2015. Validating the use of trap-collected feces for studying the gut microbiota of a small mammal (*Neotoma lepida*). Journal of Mammalogy 96: 90–93. <https://doi.org/10.1093/jmammal/gyu008>
- Lorch, J. M., C. U. Meteyer, M. J. Behr, J. G. Boyles, P. M. Cryan, A. C. Hicks, A. E. Ballmann, J. T. Coleman, D. N. Redell, D. M. Reeder, and D. S. Blehert.** 2011. Experimental infection of bats with *Geomyces destructans* causes white-nose syndrome. Nature 480: 376–378. <https://doi.org/10.1038/nature10590>
- Lorch, J. M., A. M. Minnis, C. U. Meteyer, J. A. Redell, J. P. White, H. M. Kaarakka, L. K. Muller, D. L. Lindner, M. L. Verant, V. Shearn-Bochsler, and D. S. Blehert.** 2015. The fungus *Trichophyton redellii* sp. nov. causes skin infections that resemble white-nose syndrome of hibernating bats. Journal of Wildlife Diseases 51: 36–47. <http://doi.org/10.7589/2014-05-134>
- Malloch, D., and J. M. Hubart.** 1987. An undescribed species of *Microascus* from the Cave of Ramioul. Canadian Journal of Botany 65: 2384–2388. <https://doi.org/10.1139/b87-324>
- Maser, C., and Z. Maser.** 1987. Notes on mycophagy in four species of mice in the genus *Peromyscus*. Great Basin Naturalist 47: 308–313.
- McAlpine, D. F., K. J. Vanderwolf, G. J. Forbes, and D. Malloch.** 2011. Consumption of bats (*Myotis* spp.) by raccoons (*Procyon lotor*) during an outbreak of white-nose syndrome in New Brunswick: implications for bat mortality estimates. Canadian Field-Naturalist 125: 257–260. <https://doi.org/10.22621/cfn.v125i3.1231>
- Meyer, R. T., A. Weir, and T. R. Horton.** 2015. Small-mammal consumption of hypogeous fungi in the central Adirondacks of New York. Northeastern Naturalist 22: 648–651. <https://doi.org/10.1656/045.022.0318>
- Murray, M. D.** 1961. The ecology of the louse *Polyplax serrata* (Burn.) on the mouse *Mus musculus* L. Australian Journal of Zoology 9: 1–13. <https://doi.org/10.1071/ZO9610001#sthash.eiyWA4ys.dpuf>
- Nelson, B. C., and C. R. Smith.** 1976. Ecological effects of a plague epizootic on the activities of rodents inhabiting caves at Lava Beds National Monument, California. Journal of Medical Entomology 13: 51–61. <https://doi.org/10.1093/jmedent/13.1.51>
- Peck, S. B.** 1988. A review of the cave fauna of Canada, and the composition and ecology of the invertebrate fauna of caves and mines in Ontario. Canadian Journal of Zoology 66: 1197–1213. <https://doi.org/10.1139/z88-176>
- Pyare, S., and W. S. Longland.** 2001. Patterns of ectomycorrhizal-fungi consumption by small mammals in remnant old-growth forests of the Sierra Nevada. Journal of Mammalogy 82: 681–689. [https://doi.org/10.1644/1545-1542\(2001\)082<0681:POEFCB>2.0.CO;2](https://doi.org/10.1644/1545-1542(2001)082<0681:POEFCB>2.0.CO;2)
- Rostami, A., D. Shirani, H. Shokri, A. R. Khosravi, R. Daieghazvini, and Z. Tootian.** 2010. Fungal flora of the hair coat of Persian squirrel (*Sciurus anomalus*) with and without skin lesion in Tehran, Iran. Journal of Mycologie

Medicale 20: 21–25. <https://doi.org/10.1016/j.mycmed.2009.11.004>

Sandoval-Denis, M., J. Gené, D. A. Sutton, J. F. Cano-Lira, G. S. de Hoog, C. A. Decock, N. P. Wiederhold, and J. Guarro. 2016. Redefining *Microascus*, *Scopulariopsis* and allied genera. *Perssonia* 36: 1–36. <https://doi.org/10.3767/003158516X688027>

Seifert, K., G. Morgan-Jones, W. Gams, and B. Kendrick. 2011. The Genera of Hyphomycetes. CBS-KNAW Fungal Biodiversity Centre, Utrecht, Netherlands.

Sierra, P., J. Guillot, H. Jacob, S. Bussieras, and R. Chermette. 2000. Fungal flora on cutaneous and mucosal surfaces of cats infected with feline immunodeficiency virus or feline leukemia VI. *American Journal of Veterinary Research* 61: 158–161. <https://doi.org/10.2460/ajvr.2000.61.158>

Stephenson, S., M. Slay, C. Slay, and A. Tuggle. 2007. Cave crickets (Orthoptera: Rhaphidophoridae) as vectors of Dictyostelids (Protista: Dictyosteliida). *Entomological News* 118: 292–295. [http://doi.org/10.3157/0013-872X\(2007\)118\[292:CCOAVO\]2.0.CO;2](http://doi.org/10.3157/0013-872X(2007)118[292:CCOAVO]2.0.CO;2)

Trevor-Deutsch, B. 1973. The role of hibernating bats in the winter diet of *Peromyscus* spp. (Rodentia: Cricetidae). Ph.D. thesis, Carleton University, Ottawa, Ontario, Canada.

Vanderwolf, K. J., D. F. McAlpine, G. J. Forbes, and D. Malloch. 2012. Winter bat populations and cave microclimate prior to and at the onset of white-nose syndrome in New Brunswick. *Canadian Field-Naturalist* 126: 125–134. <https://doi.org/10.22621/cfn.v126i2.1327>

Vanderwolf, K. J., D. F. McAlpine, D. Malloch, and G. J. Forbes. 2013. Ectomycota associated with hibernating cave bats in eastern Canada prior to the emergence of white-nose syndrome. *Northeastern Naturalist* 20: 115–130. <https://doi.org/10.1656/045.020.0109>

Vanderwolf, K. J., D. Malloch, and D. F. McAlpine. 2016a. Fungi on white-nose infected bats (*Myotis* spp.) in Eastern Canada show no decline in diversity associated with *Pseudogymnoascus destructans* (Ascomycota: Pseudeurotiaceae). *International Journal of Speleology* 45: 43–50. <https://doi.org/10.5038/1827-806X.45.1.1946>

Vanderwolf, K. J., D. Malloch, and D. F. McAlpine. 2016b. Ectomycota associated with arthropods from bat hibernacula in eastern Canada, with particular reference to *Pseudogymnoasucs destructans*. *Insects* 7: 16. <https://doi.org/10.3390/insects7020016>

Vanderwolf, K. J., D. Malloch, and D. F. McAlpine. 2016c. Detecting viable *Pseudogymnoascus destructans* (Ascomycota: Pseudeurotiaceae) from walls of bat hibernacula: effect of culture media. *Journal of Cave and Karst Studies* 78: 158–162. <https://doi.org/10.4311/2015MB0138>

Received 23 February 2017
Accepted 31 August 2017

Fabronia ciliaris, a Moss New to Canada from Southeastern Manitoba

RICHARD T. CANERS

Royal Alberta Museum, 9810 103A Avenue, Edmonton, Alberta T5J 0G2 Canada, and Department of Renewable Resources, University of Alberta, Edmonton, Alberta T6G 2H1 Canada; email: Richard.Caners@gov.ab.ca

Caners, Richard T. 2017. *Fabronia ciliaris*, a moss new to Canada from southeastern Manitoba. *Canadian Field-Naturalist* 131(3): 246–251. <https://doi.org/10.22621/cfn.v131i3.1961>

Fabronia ciliaris (Fabroniaceae, Bryophyta) was recently discovered in the Great Lakes–St. Lawrence forest region in southeastern Manitoba. This collection represents the first record of the species in Canada and the northernmost extent of the species in North America.

Key Words: Bryophyta; distribution; *Fabronia ciliaris*; *Fabronia pusilla*; Fabroniaceae; Great Lakes; Manitoba; moss; phyto-geography; St. Lawrence; Whiteshell Provincial Park

Introduction

In North America, the moss family Fabroniaceae contains a single genus, *Fabronia* Raddi (Fabroniaceae, Bryophyta), that is represented (McIntosh 2014) by only two species: *F. ciliaris* (Bridel) Bridel (Fabronia Moss) and *F. pusilla* Raddi (Silver Hair Moss). Several previously recognized taxa are now considered to be synonymous with *F. ciliaris*, including *F. ciliaris* var. *polycarpa* (Hooker) W. R. Buck, *F. ciliaris* var. *wrightii* (Sullivant) W. R. Buck, *F. ravenelii* Sullivant, and *F. wrightii* Sullivant (McIntosh 2014; for additional synonyms see Tropicos.org 2017).

The genus *Fabronia* in North America comprises diminutive, sparsely branched, perennial plants that often form thin and silky whitish-green mats (Buck 1994; McIntosh 2014). Leaves are tiny (0.4–0.9 mm long), mostly ovate-lanceolate, loosely appressed when dry, and terminate in linear apical cells. Leaves also have single, short costae that extend to about half the leaf length, rhomboidal laminal cells, and quadrate to short-rectangular basal cells. Plants are autoicous, with female and male reproductive structures on the same shoots. Plants regularly contain sporophytes, with erect, ovoid to pyriform capsules that have sinuose cells in their outer walls (exothecia). *Fabronia ciliaris* is distinguished from *F. pusilla* in having acute or acuminate leaf apices and low-dentate (sometimes entire) leaf margins with teeth of one cell each. *Fabronia pusilla* has acute to long-acuminate leaf apices and ciliate-dentate leaf margins with teeth often composed of more than one cell.

Fabronia ciliaris is known in North America from the United States and Mexico (Figure 1). In the United States, the species has a wide distribution, occurring mainly from the northeast to the southwest (Arizona, Arkansas, California, Colorado, Georgia, Indiana, Kansas, Kentucky, Louisiana, Michigan, Minnesota, Missouri, New Jersey, New Mexico, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Virginia, and Wisconsin) based on McIntosh (2014). Worldwide,

the species is also known from the West Indies, Central America (Guatemala), South America, Europe, eastern Asia (Japan), Pacific Islands (Hawaii, New Zealand), and Australia (McIntosh 2014). *Fabronia ciliaris* has not been reported previously for Canada. The species was not included for Canada in the Bryophyte Flora of North America (McIntosh 2014) or in the 2015 list of the General Status of Species in Canada (CESCC 2016). There are no known Canadian specimens in the digitally accessible Consortium of North American Bryophyte Herbaria (CNABH 2017) or BRYOQUEL (Faubert *et al.* 2017) databases, and, based on personal communications, there are no known Canadian specimens at multiple Canadian herbaria (ALTA, CAFB, CANM, MMMN, PMAE, UADBG, UBC, WIN; refer to Thiers 2017 for standardized, stable herbarium abbreviations) or United States herbaria with substantial Canadian bryophyte collections (F, FH, MO, NY, US). Also, Grout (1928–1940) and Crum and Anderson (1981) do not list the species for any Canadian jurisdiction.

A specimen from the University of British Columbia herbarium (UBC B56875), collected by W. B. Schofield (59600) on 27 March 1976, from “Sumas Mountain escarpment near Chilliwack”, was labelled *F. ciliaris*, but was subsequently annotated to *F. pusilla* by T. T. McIntosh in January 2008. A collection from the Pacific Northwest Herbarium at Western Washington University (WWB B-2535) by J. S. Martin (4985) on 23 July 1975, from Algoma District in northeastern Ontario, found growing on granitic rock, near Brownlee Lake, about 9.5 km east of Thessalon, was labelled “*Fabronia ciliaris* (?) (Brid.) Brid.”. However, on examination by the author, the specimen was determined to be *Hypnum pallescens* (Hedwig) P. Beauvois. *Fabronia ciliaris* is not included in the list of bryophytes for Ontario and is not ranked or tracked by the Ontario Natural Heritage Information Centre (David Bradley, personal communication, 13 January 2017).

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalists’ Club.

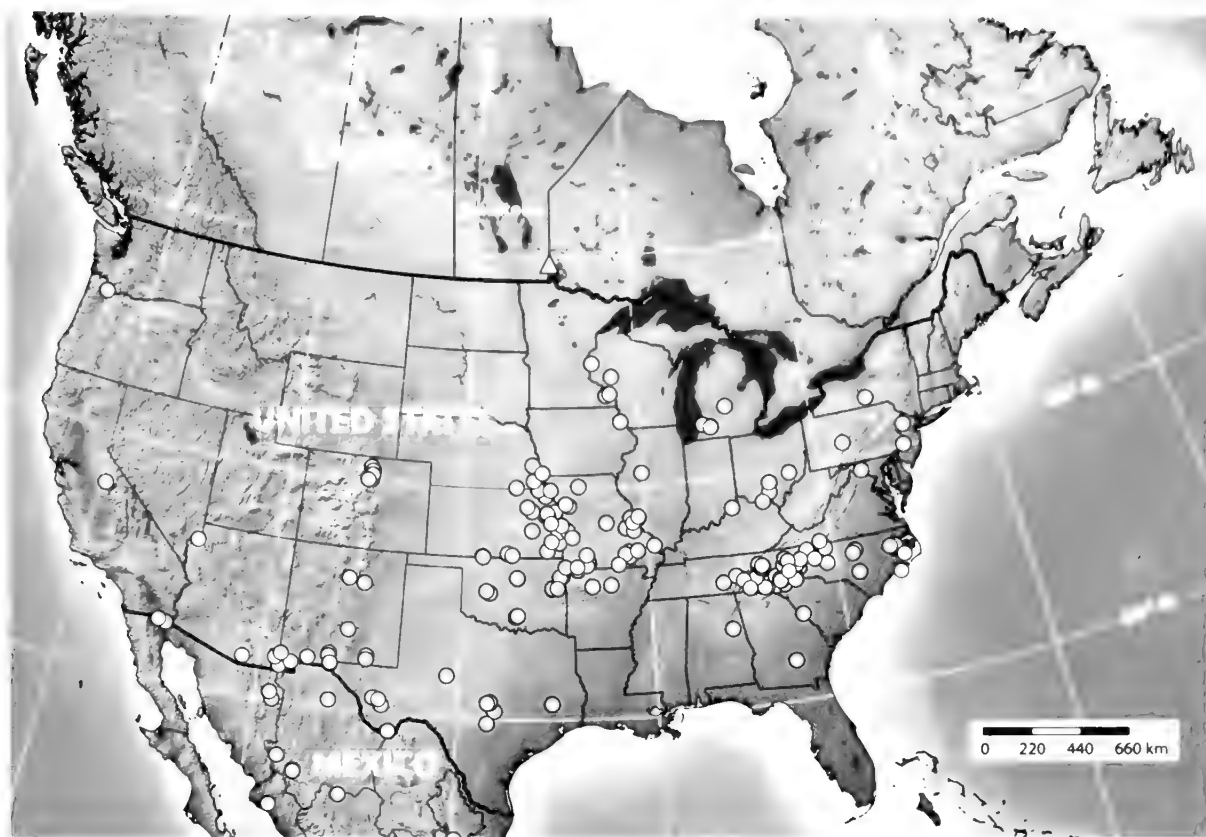


FIGURE 1. Distribution of *Fabronia ciliaris* in North America based on search results from the Consortium of North American Bryophyte Herbaria (CNABH 2017) database. Map generated and modified from SimpleMapp (Shorthouse 2010). The triangle depicts the new collection from Whiteshell Provincial Park in southeastern Manitoba, the first record for Canada. Specimens associated with data points have not been verified by the author and represent the approximate distribution for the species only.

Methods

Surveys to document bryophyte diversity in southeastern Manitoba were conducted in late September 2016. One survey was held on 27 September 2016 at Hunt Lake in Whiteshell Provincial Park, Manitoba (49°44'N, 95°10'W; 343 m elevation) under Manitoba Sustainable Development, Parks and Protected Spaces permit no. PP-PHQ-16-026. The park is situated in the Great Lakes–St. Lawrence forest region (Rainy River section) of Canada, which extends across southern and eastern Canada, from the St. Lawrence River in Quebec to its western limits in southeastern Manitoba (Rowe 1972). Climate in the vicinity of the study site has an annual daily average temperature of 2.5 °C and total annual precipitation of 630.8 mm, with 506.8 mm falling as rain (data from Indian Bay meteorological station, Manitoba; 49°37'N, 95°12'W; 327 m elevation; Environment and Climate Change Canada 2017).

Results

The survey at Whiteshell Provincial Park revealed the moss *Fabronia ciliaris* (Figure 1). The species was

growing on a forested, calcareous rock outcrop close to the lake shore (Figure 2). The tree canopy was dominated by Eastern White-cedar (*Thuja occidentalis* L.), Balsam Fir (*Abies balsamea* (L.) Mill.), and Paper Birch (*Betula papyrifera* Marshall). The cliff face supported numerous microhabitats that ranged from xeric on exposed vertical rock faces to mesic in sheltered rock crevices. *Fabronia ciliaris* was growing on a dry, vertical rock face among shoots of *Orthotrichum anomalum* Hedwig, as several scattered gametophytes containing sporophytes, over an area of several square centimetres. A collection of the species was made from this area to confirm its identity. Extended searches for the species in the vicinity were not conducted. Although the cliff face had a northwest aspect overall, the specimen was collected on a segment of the cliff that was south facing. Morphological characteristics of the specimen were typical of other collections from the northern United States (Figures 3–5; see Specimens Examined). The collection (*R. T. Caners* 7994) has been deposited at the Royal Alberta Museum herbarium (PMAE; accession no. C16.3.1).

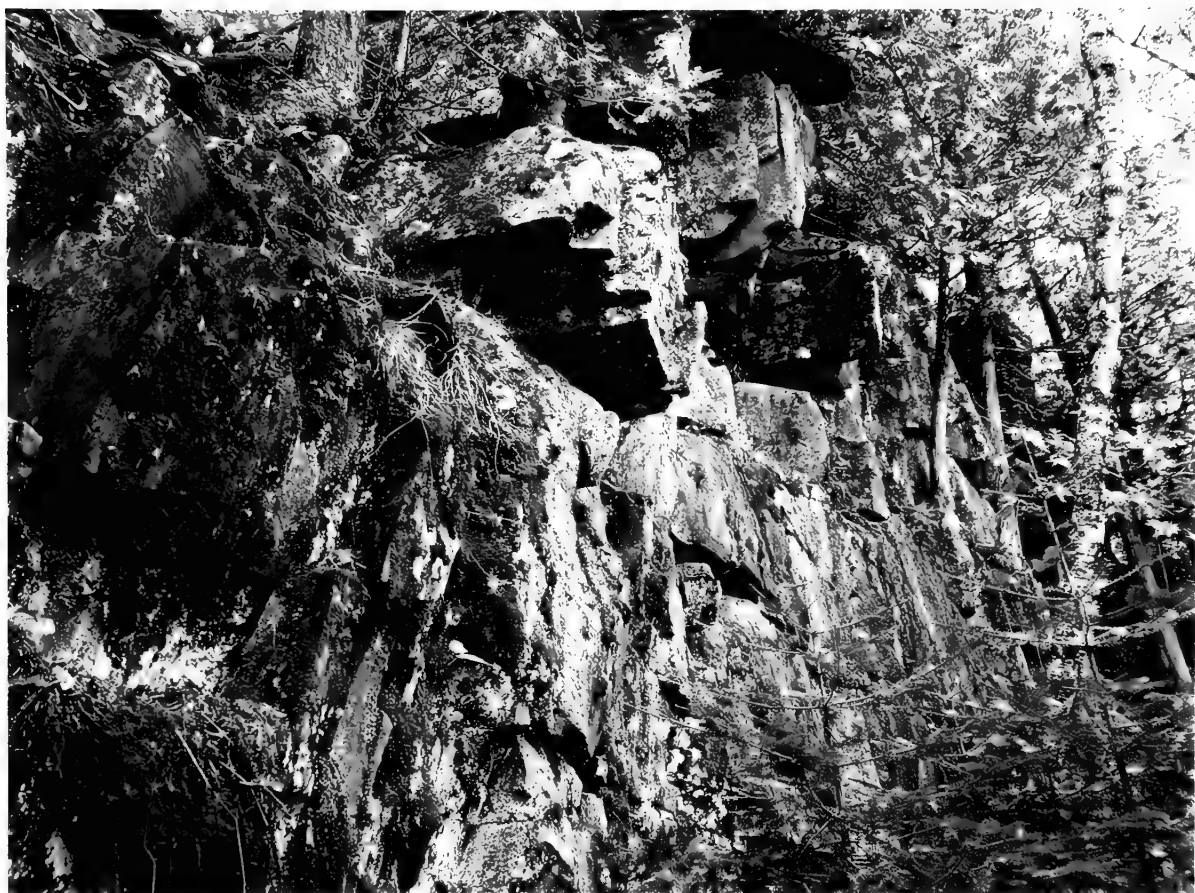


FIGURE 2. Rock outcrop in Whiteshell Provincial Park, Manitoba, where *Fabronia ciliaris* was collected. Photo: Richard Caners, 27 September 2016.

Discussion

The Great Lakes–St. Lawrence forest region in southeastern Manitoba hosts a distinctive bryophyte flora and supports a number of bryophyte species that are almost certainly restricted to this portion of the province (personal observation). The discovery of *Fabronia ciliaris* within this forest region in southeastern Manitoba represents the first record of the species in Canada and the northernmost occurrence in North America. The closest known occurrence of *F. ciliaris* is Taylors Falls, Minnesota (see Specimens Examined), more than 500 km to the southeast, where the species was first collected by J. M. Holzinger in 1895 (MO 90065179; CNABH 2017) and has been collected multiple times over the past century. In Manitoba, the species was growing on calcareous rock, a substrate type that has been reported for the species in other parts of its range in the United States (CNABH 2017; see Specimens Examined). Calcareous rock outcrops occur in the Thunder Bay region and along the north shore of Lake Superior, and these areas are closer to Taylors Falls, Minnesota, than to the Manitoba site. However, the species is also reported frequently on the bark of trees and other rock types, including granite (e.g., see

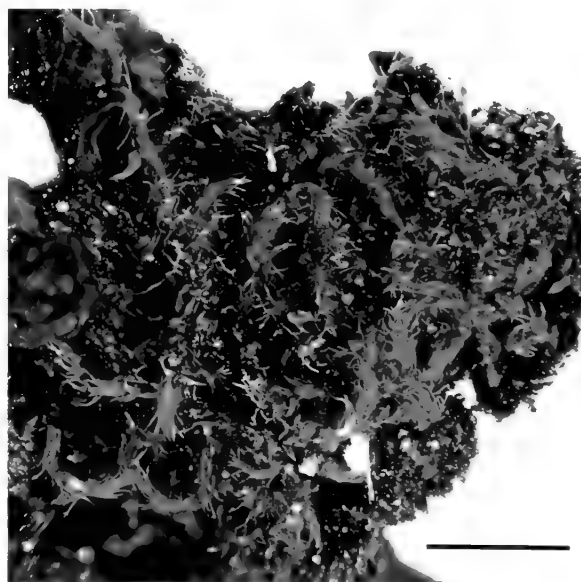


FIGURE 3. Several shoots of *Fabronia ciliaris* growing among *Orthotrichum anomalum*. The length of the scale bar represents 1.0 mm. Photo: Richard Caners.

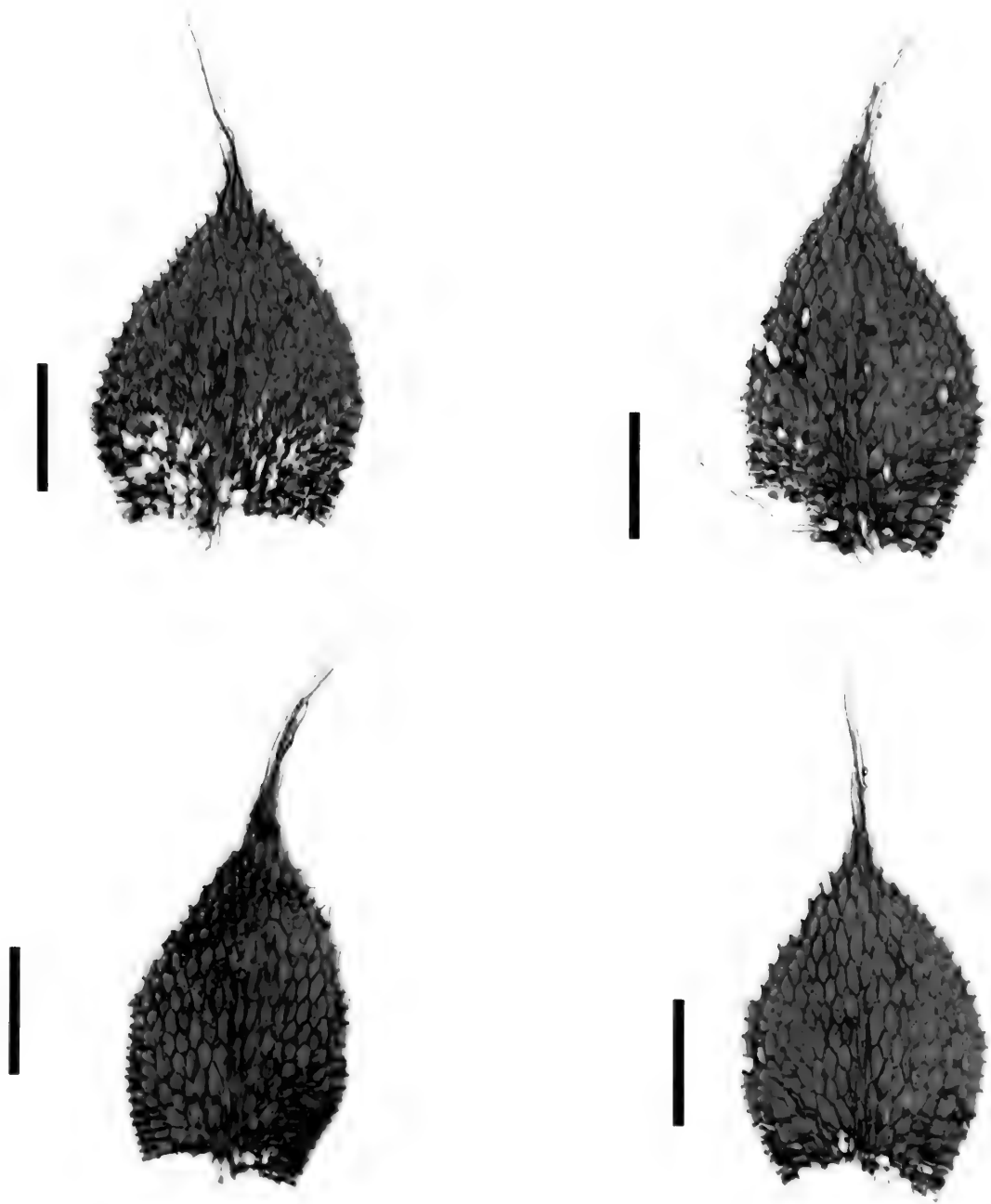


FIGURE 4. Representative stem leaves of *Fabronia ciliaris* collected in southeastern Manitoba. The length of the scale bar next to each leaf represents 0.1 mm. Photos: Richard Caners.

Specimens Examined for Taylors Falls, Minnesota), substrates that are widespread throughout the Great Lakes–St. Lawrence forest region in Canada.

Fabronia ciliaris appears to become less frequent at the most northerly latitudes in the eastern United States. This may be because of increasingly harsh growing conditions or, perhaps, because of slow expansion of the species into northern regions following the retreat of the Laurentide Ice Sheet at the end of the Wisconsin glaciation. Indeed, there are few records of the species

to the north of the maximum extent of glacial ice. Rapid retreat of ice began after about 14 000 ¹⁴C years ago (Mickelson and Colgan 2003) and was markedly faster in the area to the west of the Great Lakes compared with areas further east (Dyke 2004, 2005). This could have provided more time for the species to expand into southeastern Manitoba from Minnesota and Wisconsin. *Fabronia ciliaris* is autoicous and produces sporophytes frequently (McIntosh 2014), suggesting that it may be able to disperse over long distances by its small spores

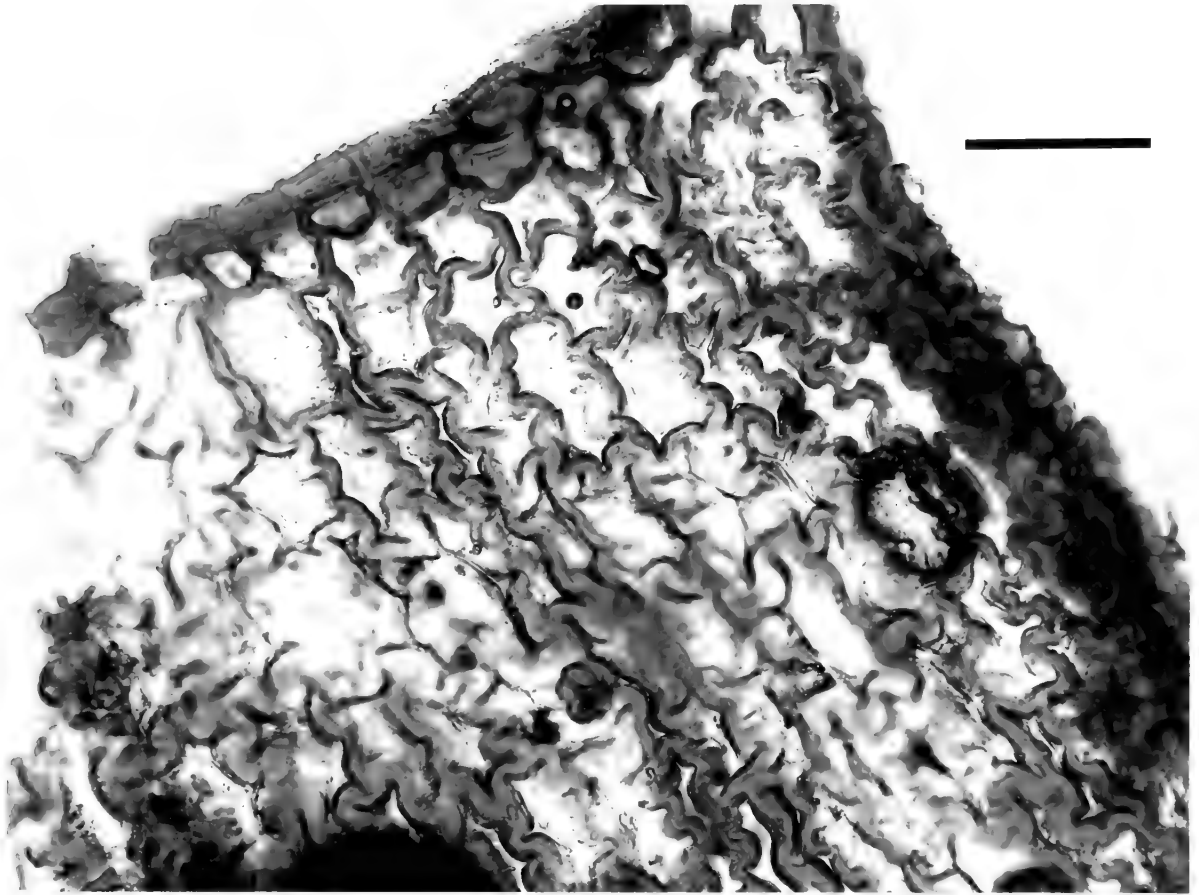


FIGURE 5. Exothecial cells from a sporophyte capsule of *Fabronia ciliaris* collected in southeastern Manitoba. The length of the scale bar represents 0.1 mm. Photo: Richard Caners.

(9–15 μm ; Lawton 1971). The lack of records in Canada to date suggests that the Great Lakes could possibly represent a barrier to expansion into northern regions. There have been relatively more collectors in southern Ontario than in many other parts of the country (personal observation), providing opportunity for *F. ciliaris* to have been reported from this area in the past. However, there still remain large areas of under-surveyed habitat within the Great Lakes–St. Lawrence forest region, especially to the west of Lake Superior and the northernmost part of the forest region, suggesting there may be other undiscovered colonies in the region.

The only other species of *Fabronia* in North America is *F. pusilla*. This species occurs mostly in the west, where it is known in the United States from Arizona, California, Colorado, Idaho, Oregon, and Washington State, and in Mexico from Baja California Sur (McIntosh 2014). In Canada, *F. pusilla* is known from a single site on sandstone in south-central British Columbia, where it reaches the northern extent of its range in North America (COSEWIC 2002, 2012; British Columbia Recovery Team 2007) and is listed as endangered under the federal *Species at Risk Act* (SARA Registry 2017). *Fabronia ciliaris* may similarly reach

its presumed northernmost extent in southeastern Manitoba, but surveys are needed to assess its distribution in Canada. *Fabronia ciliaris* risks being overlooked because of its small size; however, the survey that first detected this species in Canada was not a targeted survey.

Fabronia ciliaris Specimens Examined

UNITED STATES: KANSAS. Cherokee County: 5 miles (8 km) east of Baxter Springs, on trunk of bur oak, oak-hickory ravine, 29 July 1969, *R. R. Ireland* 22595 (ALTA 044458). MINNESOTA. Chicago County: Taylors Falls, St. Croix River, on granite rock, 24 August 1966, *D. H. Vitt* 409 (ALTA 044441). MISSOURI. Barry County: cedar glade just south of Roaring River State Park on Hwy. F, beneath limestone ledge, 23 May 1973, *P. L. Redfearn, Jr.* 28483 (ALTA 044442); Greene County: wooded east-facing slope above James River just below Lake Springfield Dam, alt. ca. 1300 feet (400 m), common on trunks of red cedar, 1 November 1985, *P. L. Redfearn, Jr. & A. Rushing* 33569 (ALTA 044456); Pike County: Louisiana, Stark Brothers Nursery retain building, on large tree trunk in commercial nursery area, 30 May 1994, *D. H. Vitt s.n.* (ALTA 044451); Vernon County: 3 miles

(4.8 km) west of El Dorado Springs, north along county line road, on trunk of dead deciduous tree, 26 August 1966, *R. R. Ireland* 9815 (PMAE C95.1.19021). NEBRASKA. Jefferson County: 5 miles (8 km) south of Fairbury on Hwy 15 and 1/4 mile (0.4 km) east, 1/2W, Sec.14, T1N, R2E, upland tributary, moss on trunk of *Ulmus*, 0–2.5 feet (0–0.8 m) on NE-side, 1 October 1975, *S. P. Churchill* 6845 (PMAE C95.1.19025). OKLAHOMA. Payne County: Stillwater, southeast of OSU campus, 8 feet (2.4 m) high on bark of elm tree, 16 January 1959, *C. D. Bird* 2920 (PMAE C95.1.19020).

Acknowledgements

The Royal Alberta Museum (Government of Alberta) supported the survey financially and Lisa Matthias assisted in the field. Jason Kelly (Manitoba Sustainable Development, Parks and Protected Spaces) provided the research and collection permits. The Pacific Northwest Herbarium at Western Washington University (WWB) provided a loan of the collection from Algoma District, Ontario, Canada. Staff from the following herbaria kindly responded to inquiries about collections: CANM, F, FH, MMMN, MO, NY, UBC, US, WIN, WWB, and WTU. David Bradley (Ontario Natural Heritage Information Centre) responded to questions about the Ontario tracking list for bryophytes. An earlier version of the manuscript was improved by helpful comments from J. Doubt, J. Harpel, D. Lepitzki, and J. Saarela.

Literature Cited

- British Columbia Bryophyte Recovery Team.** 2007. Recovery strategy for the silver hair moss (*Fabronia pusilla* Rad-di) in British Columbia. British Columbia Ministry of Environment, Victoria, British Columbia, Canada.
- Buck, W. R.** 1994. Fabroniaceae. Pages 860–867 in *The Moss Flora of Mexico*. Edited by A. J. Sharp, H. Crum, and P. M. Eckel. Memoirs of the New York Botanical Garden 69. NYBG Press, New York, New York, USA.
- CESCC (Canadian Endangered Species Conservation Council).** 2016. Wild species 2015: the general status of species in Canada. National General Status Working Group, Ottawa, Ontario, Canada. Accessed 14 August 2017. http://www.registrelep-sararegistry.gc.ca/virtual_sara/files/reports/Wild%20Species%202015.pdf.
- CNABH (Consortium of North American Bryophyte Herbaria).** 2017. Consortium of North American Bryophyte Herbaria. Accessed 14 August 2017. <http://bryophyteportal.org>.
- COSEWIC (Committee on the Status of Endangered Wildlife in Canada).** 2002. COSEWIC assessment and status report on the Silver Hair Moss *Fabronia pusilla* in Canada. COSEWIC, Ottawa, Ontario, Canada.
- COSEWIC (Committee on the Status of Endangered Wildlife in Canada).** 2012. COSEWIC status appraisal summary on the Silver Hair Moss *Fabronia pusilla* in Canada. COSEWIC, Ottawa, Ontario, Canada.
- Crum, H. A., and L. E. Anderson.** 1981. Mosses of Eastern North America. Volume 2. Columbia University Press, New York, New York, USA.
- Dyke, A. S.** 2004. An outline of North American deglaciation with emphasis on central and northern Canada. Pages 373–424 in *Quaternary Glaciations: Extent and Chronology. Part II: North America*. Edited by J. Ehlers and P. L. Gibbard. Elsevier, Amsterdam, Netherlands. [https://doi.org/10.1016/S1571-0866\(04\)80209-4](https://doi.org/10.1016/S1571-0866(04)80209-4)
- Dyke, A. S.** 2005. Late Quaternary vegetation history of northern North America based on pollen, macrofossil, and faunal remains. *Géographie physique et Quaternaire* 59: 211–262. <https://doi.org/10.7202/014755ar>
- Environment and Climate Change Canada.** 2017. Temperature and precipitation graph for 1981 to 2010 Canadian climate normals: Indian Bay. Environment and Climate Change Canada, Ottawa, Ontario, Canada. Accessed 14 August 2017. <https://tinyurl.com/ya9zylkx>.
- Faubert, J., S. Leclerc, A. Lavoie, M. Lapointe, S. Nadeau, M. Lamond, et collaborateurs.** 2017. Base de données des bryophytes du Québec–Labrador (BRYOQUEL). Société québécoise de bryologie, Saint-Valérien-de-Rimouski, Quebec, Canada. Accessed 14 August 2017. <http://www.societequebecoisedebryologie.org/Bryoquel.html>.
- Grout, A. J.** 1928–1940. Moss Flora of North America, North of Mexico. Volume 3. Newfane, Vermont, and New York, New York, USA.
- Lawton, E.** 1971. Moss Flora of the Pacific Northwest. Hattori Botanical Laboratory, Nichinan, Miyazaki, Japan.
- McIntosh, T. T.** 2014. Fabroniaceae. Pages 477–478 in *Flora of North America: Volume 28, Bryophytes: Mosses, Part 2*. Edited by Flora of North America Editorial Committee. Oxford University Press, New York, New York, USA.
- Mickelson, D. M., and P. M. Colgan.** 2003. The southern Laurentide Ice Sheet. *Developments in Quaternary Science* 1: 1–16. [https://doi.org/10.1016/S1571-0866\(03\)01001-7](https://doi.org/10.1016/S1571-0866(03)01001-7)
- Rowe, J. S.** 1972. Forest regions of Canada. Canadian Forest Service publication no. 1300. Department of the Environment, Ottawa, Ontario, Canada.
- SARA (Species at Risk) Registry.** 2017. Species profile, Silver Hair Moss. Accessed 14 August 2017. http://www.registrelep-sararegistry.gc.ca/species-speciesDetails_e.cfm?sid=741.
- Shorthouse, D. P.** 2010. SimpleMappr: an online tool to produce publication-quality point maps. Accessed 14 August 2017. <http://www.simplemappr.net>.
- Thiers, B.** 2017. Index herbariorum: a global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium. Accessed 14 August 2017. <http://sweetgum.nybg.org/science/ih>.
- Tropicos.org.** 2017. Quick name search. Missouri Botanical Garden, St. Louis, Missouri, USA. Accessed 14 August 2017. <http://www.tropicos.org>.

Received 16 June 2017

Accepted 27 September 2017

Note

River Otter (*Lontra canadensis*) Killed by Wolves (*Canis lupus*) during Winter in Northern Minnesota

THOMAS D. GABLE^{1,2}, STEVE K. WINDELS¹, and IAN C. RAUTIO¹

¹Voyageurs National Park, 360 Highway 11 E, International Falls, Minnesota 56649 USA

²Corresponding author: thomasd.gable@gmail.com

Gable, Thomas. D., Steve K. Windels, and Ian C. Rautio. 2017. River Otter (*Lontra canadensis*) killed by wolves (*Canis lupus*) during winter in Northern Minnesota. *Canadian Field-Naturalist* 131(3): 252–253. <https://doi.org/10.22621/cfn.v131i3.1913>

Few accounts exist of Gray Wolves (*Canis lupus*) killing small sympatric mammalian predators. In January 2017, we observed a River Otter (*Lontra canadensis*) that had been killed by wolves on the ice in Voyageurs National Park, Minnesota. This is one of only a few documented instances of wolves killing otters.

Key Words: River Otter; Gray Wolf; predation; kill site; Minnesota; *Canis lupus*; *Lontra canadensis*

Gray Wolves (*Canis lupus*) predominantly hunt, kill, and consume ungulates and small mammalian prey, such as beavers (*Castor* spp.) and hares (*Lepus* spp.; Mech *et al.* 2015; Gable *et al.* 2016; Newsome *et al.* 2016). Wolves will also kill medium to large sympatric predators, such as bears (*Ursus* spp.), Cougars (*Puma concolor*), and Coyotes (*Canis latrans*) possibly to eliminate competition for resources (Rogers and Mech 1981; Ballard *et al.* 2003; Berger *et al.* 2008). However, there are anecdotal accounts of wolves killing small sympatric mammalian predators (primarily mustelids) with whom they do not directly compete (White *et al.* 2002; Palacios and Mech 2010). Such accounts are rare, but they provide information about causes of natural mortality in small predator populations as well as the effect of wolves as predators on small predator communities (Ballard *et al.* 2003).

On 30 January 2017, we found a River Otter (*Lontra canadensis*) carcass on the ice near the southern shore of Rainy Lake in Voyageurs National Park, Minnesota (48°30'N, 93°50'W). The otter carcass was frozen and had not been consumed, but appeared to have been killed recently. Several wolf tracks were present in the snow around the carcass, and we found no evidence of other predators nearby; we could not determine how many wolves were involved because of the concentration of tracks. We followed the wolf tracks, drag marks (presumably from the wolves moving the carcass), and general disturbance in the snow (i.e., snow packed down from wolves) from the otter carcass to where the encounter appeared to have started (~15 m from the carcass). We did not find any blood or hair in this area, which is not surprising given the cause of death (see below) and that wolves did not consume the carcass. We also could not determine the activities of either the wolves or otter before the encounter, for example, whether a chase had occurred, because of the trampled snow. The beginning of the encounter was not near any

visible opening in the ice, and we suspect the otter was likely moving across the frozen lake when wolves found and killed it. When searching this area, we also found a recent (< 3 days) wolf-killed White-tailed Deer (*Odocoileus virginianus*) < 1.5 km from the location of the otter carcass. Wolves had consumed most of the deer carcass.

We conducted a field necropsy of the otter carcass to determine cause of death. We did not see any visible external injuries except for two 1-cm holes on the back right leg and anus where we assume birds had picked at the carcass. Once we removed the hide, we found severe hemorrhaging and trauma on the right side of the abdomen and rib cage, confirming that these wounds occurred while the otter was alive. We found two puncture wounds on the abdomen which were about 4 cm apart — roughly the spread of wolf canines, 3.5–5.0 cm (Elbroch 2006) — and several ribs had been crushed. We also found two puncture wounds in the hide that corresponded to the puncture wounds on the abdomen. In addition, the proximal portion of the cranium (parietal, temporal, and occipital bones) had been crushed and there was a laceration/puncture wound (3 cm × 2 cm), which had not been visible during external examination, on the right proximal side of the cranium. However, we are unsure whether this wound was from a wolf canine entering from the outside or from shattered skull bone puncturing the muscle tissue from the inside. We found no other evidence of injury and concluded that the otter likely died from blunt force trauma because its cranium and rib cage were crushed.

Based on necropsy results and wolf sign at the otter carcass, we are confident that wolves killed the otter. Wolves are likely the only predator during winter in Voyageurs National Park that possess the bite strength necessary to crush an otter skull. Few reports exist of wolves killing otters even though the two are sympatric throughout much of northern North America (Mech and

Boitani 2010; Serfass *et al.* 2015). For example, Stenlund (1955) stated that he occasionally found wolf-killed otters in northern Minnesota during the winter, but provided no additional information about these kills. Furthermore, previous work in Voyageurs National Park documented a radio-tagged otter that was killed and partly consumed by a wolf in early September (Route and Peterson 1991). How frequently wolves kill otters is unknown, as the natural mortality of River Otters is not well documented or understood (Gorman *et al.* 2008). Interestingly, otter fur has not been found in any of the ~ 4000 wolf scats collected in Voyageurs National Park during intensive wolf diet studies conducted from 1988 to 1989 (Gogan *et al.* 2004) and from 2012 to 2016 (Chenaux-Ibrahim 2015; Gable *et al.* 2017; Voyageurs National Park, unpublished data). However, if wolves do not consume otters after killing them, as we observed, then scat-based wolf diet estimates would not reflect the frequency of wolf predation on otters.

Acknowledgements

We thank Voyageurs National Park for providing support for this project. We also thank Visitor and Resource Protection staff at Voyageurs National Park for assistance in documenting this observation.

Literature Cited

- Ballard, W. B., L. N. Carbyn, and D. W. Smith. 2003. Wolf interactions with non-prey. Pages 259–271 in *Wolves: Behavior, Ecology, and Conservation*. Edited by L. D. Mech and L. Boitani. University of Chicago Press, Chicago, Illinois, USA.
- Berger, K. M., E. M. Gese, and J. Berger. 2008. Indirect effects and traditional trophic cascades: a test involving wolves, coyotes, and pronghorn. *Ecology* 89: 818–828. <https://doi.org/10.1890/07-0193.1>
- Chenaux-Ibrahim, Y. 2015. Seasonal diet composition of gray wolves (*Canis lupus*) in northeastern Minnesota determined by scat analysis. M.Sc. thesis, University of Minnesota-Duluth, Duluth, Minnesota, USA.
- Elbroch, M. 2006. *Animal Skulls: a Guide to North American Species*. Stackpole Books, Mechanicsburg, Pennsylvania, USA.
- Gable, T. D., S. K. Windels, and J. G. Bruggink. 2017. The problems with pooling poop: confronting sampling method biases in wolf (*Canis lupus*) diet studies. *Canadian Journal of Zoology* 95: 843–851. <https://doi.org/10.1139/cjz-2016-0308>
- Gable, T. D., S. K. Windels, J. G. Bruggink, and A. T. Homkes. 2016. Where and how wolves (*Canis lupus*) kill beavers (*Castor canadensis*). *PLoS ONE* 11(12): e0165537. <https://doi.org/10.1371/journal.pone.0165537>
- Gogan, P. J. P., W. T. Route, E. M. Oleva, N. Thomas, D. Kuehn, and K. M. Podrutzny. 2004. Gray wolves in and adjacent to Voyageurs National Park, Minnesota: research and synthesis, 1987–1991. United States Department of the Interior, National Park Service, Midwest Regional Office, Omaha, Nebraska, USA.
- Gorman, T. A., B. R. McMillan, and J. D. Erb. 2008. Survival and cause-specific mortality of a protected population of river otters in Minnesota. *American Midland Naturalist* 159: 98–109. [https://doi.org/10.1674/0003-0031\(2008\)159\[98:sacmoa\]2.0.co;2](https://doi.org/10.1674/0003-0031(2008)159[98:sacmoa]2.0.co;2)
- Mech, L. D., and L. Boitani (IUCN SSC Wolf Specialist Group). 2010. *Canis lupus*. In *The IUCN Red List of Threatened Species*. International Union for Conservation of Nature and Natural Resources, Gland, Switzerland. <https://doi.org/10.2305/IUCN.UK.2010-4.RLTS.T3746A10049204.en>
- Mech, L. D., D. W. Smith, and D. R. MacNulty. 2015. *Wolves on the Hunt: the Behavior of Wolves Hunting Wild Prey*. University of Chicago Press, Chicago, Illinois, USA.
- Newsome, T. M., L. Boitani, G. Chapron, P. Ciucci, C. R. Dickman, J. A. Dellinger, J. V. López-Bao, R. O. Peterson, C. R. Shores, A. J. Wirsing, and W. J. Ripple. 2016. Food habits of the world's grey wolves. *Mammal Review* 46: 255–269. <https://doi.org/10.1111/mam.12067>
- Palacios, V., and L. D. Mech. 2010. Problems with studying wolf predation on small prey in summer via global positioning system collars. *European Journal of Wildlife Research* 57: 149–156. <https://doi.org/10.1007/s10344-010-0408-7>
- Rogers, L. L., and L. D. Mech. 1981. Interactions of wolves and black bears in northeastern Minnesota. *Journal of Mammalogy* 62: 434–436. <https://doi.org/10.2307/1380735>
- Route, W. T., and R. O. Peterson. 1991. An incident of wolf, *Canis lupus*, predation on a river otter, *Lutra canadensis*, in Minnesota. *Canadian Journal of Wildlife Research* 105: 567–568. Accessed 21 December 2017. <https://www.biodiversitylibrary.org/page/34349085#page/587/mode/1up>
- Serfass, T., S. S. Evans, and P. Polechla. 2015. *Lontra canadensis*. In *The IUCN Red List of Threatened Species*. International Union for Conservation of Nature and Natural Resources, Gland, Switzerland. <https://doi.org/10.2305/IUCN.UK.2015-2.RLTS.T12302A21936349.en>
- Stenlund, M. 1955. A field study of the timber wolf (*Canis lupus*) on the Superior National Forest, Minnesota. Technical bulletin 1–55. Minnesota Department of Conservation, St. Paul, Minnesota, USA.
- White, K. S., H. N. Golden, K. J. Hundertmark, and G. R. Lee. 2002. Predation by wolves, *Canis lupus*, on wolverines, *Gulo gulo*, and an American marten, *Martes americana*, in Alaska. *Canadian Field-Naturalist* 116: 132–134. Accessed 21 December 2017. <https://www.biodiversitylibrary.org/item/109250#page/140/mode/1up>

Received 17 March 2017

Accepted 15 September 2017

Note

Adult Snapping Turtle (*Chelydra serpentina*) Feeding on Goldeneye Embryos of Pumpkinseed (*Lepomis gibbosus*) in Defended Nests

ALEXANDER J. BUSE¹, MEGHAN A. DOUGLAS¹, THOMAS N. GIGUÈRE¹, and BEREN W. ROBINSON^{1,2}

¹Department of Integrative Biology, University of Guelph, Guelph, Ontario N1G 2W1 Canada

²Corresponding author: berenrob@uoguelph.ca

Buse, Alexander J., Meghan A. Douglas, Thomas N. Giguère, and Beren W. Robinson. 2017. Adult Snapping Turtle (*Chelydra serpentina*) feeding on goldeneye embryos of Pumpkinseed (*Lepomis gibbosus*) in defended nests. *Canadian Field-Naturalist* 131(3): 254–257. <https://doi.org/10.22621/cfn.v131i3.1859>

Rarely observed predatory behaviour of adult Snapping Turtles (*Chelydra serpentina*) was recorded using remote video technology. We observed turtles inspecting and, in one case, apparently feeding on goldeneye stage embryos (< 3 mm) from defended nests of Pumpkinseed (*Lepomis gibbosus*). This novel behaviour was limited to nests in a secluded bay and was not observed at nests located along exposed shorelines or on shallow shoals in the deep open water habitat of an inland oligotrophic lake. The benefit of feeding on small prey is likely enhanced by embryos being clustered in nests and by an abundance of sunfish nests. Low-cost and low-intrusion video technology provides excellent opportunities, even in aquatic systems, to document novel predator and prey behaviours.

Key Words: Remote video recording; predator–prey interaction; fish embryos; nesting Pumpkinseed; *Lepomis gibbosus*; Snapping Turtle ram-feeding; *Chelydra serpentina*

Snapping Turtle (*Chelydra serpentina*) originated 40 million years ago (Van Devender and Tessman 1975) and has one of the largest geographic ranges of any freshwater turtle in the Americas (Ernst and Lovich 2009). It swims and walks along the bottom in a variety of lentic and slow-moving lotic waters. A diverse foraging ecology may contribute to its evolutionary persistence and extensive range. Fish, birds, anurans, crayfish, and many small benthic invertebrates can all occur in their diet (Herrel *et al.* 2002; Spotila and Bell 2008; Lawrence and Peterson 2010). Although direct evidence in the field is rare, adults are thought to use sit-and-wait ambush tactics to capture live fish (Punzo 1975; Spotila and Bell 2008; Ernst and Lovich 2009), but they also scavenge dead prey (Schneider 1998; Spotila and Bell 2008). Vegetation frequently appears in the diet (Ernst and Lovich 2009), particularly when animal prey are rare and vegetation is abundant (Moldowan *et al.* 2015) and more frequently in the southern part of the range (Spotila and Bell 2008). However, ingesting vegetation may also occur when feeding on high densities of attached invertebrates (Harper and Bolen 1996). In large adults, it is unclear whether the eggs of fishes, salamanders and frogs, tiny aquatic insect larvae, benthic invertebrates, and duckweed (Lemnaceae) are ingested as a consequence of feeding on gravid females, on the benthos, or in some other habitat that concentrates these items (Ratz *et al.* 1999; Spotila and Bell 2008). Recent advances in digital cameras can provide opportunities to observe active predation by such elusive animals to clarify their feeding behaviour.

Snapping Turtles capture their prey solely with their mouths, but have a variety of specializations that permit

a diverse diet, including a strong biting force (Herrel *et al.* 2002), rapid prey strike (Lauder and Prendergrast 1992), and rapid protein digestion (Spotila and Bell 2008). Prey cannot be consumed out of water, although it can be captured there (Summers *et al.* 1998; Ernst and Lovich 2009). The feeding kinematics of turtles is challenging to assess (Bels *et al.* 2008), but in water, Snapping Turtles predominantly use a ram-feeding mode (Lauder and Prendergrast 1992; Summers *et al.* 1998) contrary to earlier theories suggesting that suction feeding dominates (Lagler 1943; reviewed in Ernst and Lovich 2009). Ram feeding is typically characteristic of predators that feed on elusive prey that can detect and escape rapid predator strikes, whereas suction feeding is often used to capture smaller prey in water (Wainwright *et al.* 2001). Thus, a ram-feeding mode raises questions about how and why Snapping Turtles may feed on small prey.

Diet diversity in Snapping Turtles is enhanced by the ability to modulate ram-feeding kinematics depending on the prey (Lauder and Prendergrast 1992), although strike performance is also affected by temperature (Vervust *et al.* 2011). For large predators, the energetic and opportunity costs of feeding on small and dispersed prey increasingly outweigh the nutritional gain and, thus, the profitability of small prey can be enhanced when prey are aggregated, such as egg masses of frogs and salamanders (Spotila and Bell 2008; Moldowan *et al.* 2015), or have a high local density, such as blooms of duckweed (Kadlec 1962).

Here, we report field observations made via remote videotaping of adult Snapping Turtles inspecting the defended nests of Pumpkinseed (*Lepomis gibbosus*) and

in one case apparently feeding on goldeneye-stage embryos (i.e., non-mobile post hatch "free" embryos, < 3 mm total length, with yolk sacs, that have not yet started to feed exogenously; Auer 1982). This is the first time this feeding behaviour has been reported in adult Snapping Turtles.

Observations of Snapping Turtles and nesting Pumpkinseed were made in Ashby Lake (45°05'N, 77°21'W) in the Addington Highlands of Ontario, Canada, a 259-ha oligotrophic Canadian Shield lake with a maximum depth of 36.6 m (Jastrebski and Robinson 2004) as part of ongoing studies of the reproductive biology of Pumpkinseed. Waterproof 'Gideon' action sports camcorders by Wasp cameras (Cedar Electronics, Chicago, Illinois, USA) attached to bricks were deployed for 4 h on the lake bottom, about 1 m from nest-guarding male Pumpkinseeds whose nests contained either fertilized eggs or hatched goldeneye-stage embryos based on inspection by a skin diver. In this and other post-glacial lakes, Pumpkinseed males construct, maintain, and defend nests in the littoral habitat of secluded bays, along more open shorelines exposed to deeper open-water lake habitat, and on shallow submerged rocky shoals in deep open-water habitat (Jastrebski and Robinson 2004). Cameras in littoral and open shoreline habitats were positioned on the shoreward side of each nest facing toward deeper water for the largest field of view of potential aquatic predators. Approximately 600 h of video capturing 125 nesting Pumpkinseed from three lake habitats were obtained between 1 June and 25 July 2015.

We define nest inspection by a Snapping Turtle as its presence at a Pumpkinseed nest with at least one head-down posture within a few centimetres of the substrate inside the nest perimeter. This is consistent with either visual or olfactory searching behaviour. We also recorded Snapping Turtles in the field of view but not visiting the focal nest. Turtles were not marked or otherwise handled in this study. Observations followed animal care and use guidelines at the University of Guelph developed in accordance with the standards of Good Animal Practice certification by the Canadian Council on Animal Care.

Snapping Turtles appeared in ten of the 125 recordings. Nine sightings occurred in 49 recordings made in a single 1-ha bay (one sighting 10 June, four on 25 June, four on 7 July); one sighting in 37 recordings from open shoreline nests (11 June); and none in 39 recordings of nests on shoals in open waters. Turtles could be clearly seen in seven recordings and were in the background in the other three.

At least two different adult turtles were involved in the greatest number of nest inspections in the bay; one could be identified by a distinct deformation on the second claw on its front left leg (see Video S1). This individual was observed in three recordings (involving two nest inspections and one swim-by, all on 25 June). One or more individuals without obvious distinguishing fea-

tures were observed at close proximity in three additional recordings, all involving nest inspections (one on 10 June and two on 7 July). The individual observed in a recording of the nest in the open shoreline habitat could also be distinguished by a prominent white patch on top of its head (not observed elsewhere); it swam in close proximity to the sunfish nest, but did not inspect it.

The turtles observed were large, with carapace lengths equal to or exceeding the diameter of the Pumpkinseed nests, which are typically 25–40 cm in diameter. The frequency of nest visits by turtles did not depend on time of day (six observations in the morning versus four in the afternoon, 1-sample $z = 0.63$, $P = 0.74$) and the time spent inspecting a nest varied from 5 s to 14:32 min:s (mean duration of five visits \pm 3:59 min:s, SE 2:47). None of the nest-guarding male Pumpkinseeds permanently abandoned its nest after any turtle inspection. Sunfish also did not engage in "mobbing" behaviour in response to Snapping Turtles as reported for Bluegills (*Lepomis macrochirus*; Dominey 1983).

Active inspection of a sunfish nest occurred in five out of ten recordings. In one of these, we observed a turtle making a very long inspection and apparently feeding on goldeneye embryos in a nest at a water depth of about 1 m (Video S1). We estimate the anterior carapace width of this turtle to be 25–30 cm (based on an *in situ* estimate of the size of the nest-guarding male sunfish by a diver). The animal remained submerged and in view for 14:32 min:s, where 13:32 min:s was spent inside the perimeter of the focal sunfish nest. The turtle came into view from deeper water and stopped at a distance of 2–3 m, after which it changed direction and approached the nest. The turtle stopped with its front legs resting inside the nest perimeter and directed its head to bite at the substrate in the nest centre. It raised its head up in a forward-facing position, made gulping actions, and wriggling embryos escaped from its nostrils and rapidly sank to the nest substrate. At this point, the guarding male sunfish darted at the head of the turtle and retreated over an interval of less than 0.25 s. The turtle jerked its head downwards two more times at the nest substrate during the time inside the nest, but it was not clear whether embryos were taken in or escaped from its nostrils during these additional actions. During the 810 s the turtle was inside the nest, it spent only 134 s "nosing" at the nest bottom and swallowing (17% of total time); during the remainder of the time, it raised its head to a forward position and remained still. At high playback speeds, its eyes can be seen following the nest-guarding male and other Pumpkinseeds hovering nearby until it leaves.

Predator prey interactions are difficult to observe because they are unpredictable in time and space and often occur over short intervals (Lawrence and Peterson 2010). We confirm the utility of remote cameras for observing undiscovered or rare behaviour in aquatic

habitats by providing the first direct observations of adult Snapping Turtles visiting and inspecting active Pumpkinseed nests and, in one case, apparently feeding on the clustered embryos there. Large turtles feeding on very small prey demonstrates the diverse feeding repertoire of adult Snapping Turtles.

Sunfish embryos could be a valuable source of nutrients for Snapping Turtles, especially in this oligotrophic lake with its low density of aquatic plants. Sunfish males typically construct nests in shallow inshore habitats well within the diving range (< 2 m) of these turtles. Eggs and embryos are rich in fat and usually aggregate in the centre of a nest depression where they are defended from predators (Scott and Crossman 1998). From 500 to 5000 embryos can be available in a nest over a 3–5-day interval before larvae disperse (Scott and Crossman 1998). Nests are spatially and temporally predictable and, thus, could be visited repeatedly by a nest predator over the 2-month spawning season (starting when waters reach 20°C and ending here in early August). Pumpkinseed nests are common: 30–50 active nests were present in the 1-ha bay where turtle activity was highest and well within the summer home range size of 2–10 ha reported for adult Snapping Turtles elsewhere (Pettit *et al.* 1995). These features reduce the costs to a Snapping Turtle of foraging for embryos, particularly as the abundance of active sunfish nests increases.

This predatory behaviour may be rare, as we observed a feeding attempt at only one of the five nests inspected among 49 nests recorded in the shallow bay. It is also not clear what factors influence whether a turtle will feed on larvae during a nest inspection or why larvae leaked from the turtles nostrils after being taken in. A forward-facing camera attached to the carapace of a Snapping Turtle could be used to estimate the prevalence of this foraging behaviour and, possibly, reveal other novel interactions between Snapping Turtles and nest-guarding male Pumpkinseed that affect whether fish larvae are consumed.

Acknowledgements

W. Jarvis assisted in the making of videos at Ashby Lake in 2015. J. Kaur, E. Jane, M. McKenzie, A. Begley, J. Silver, M. Sansom, N. Welch, J. Kenny, E. Au, R. Bahgat, and O. Robinson all reviewed videos. We are grateful to R. and C. Gautier and the members of the Ashby Lake Protective Association for their support of our fieldwork. WASPCam provided material support and the Natural Science and Engineering Research Council of Canada provided financial support for our discovery research on aquatic ecology.

Literature Cited

Auer, N. A. 1982. Identification of larval fishes of the Great Lakes basin with emphasis on the Lake Michigan drainage. Special publication 82. Great Lakes Fishery Commission, Ann Arbor, Michigan, USA.

- Bels, V., S. Baussart, J. Davenport, M. Shorten, R. M. O’Riordan, S. Renous, and J. L. Davenport.** 2008. Functional evolution of feeding behavior in turtles. Pages 187–212 in *Biology of Turtles: From Structures to Strategies of Life*. Edited by J. Wyneken, M. H. Godfrey, and V. Bels. CRC Press, Taylor and Francis Group, Boca Raton, Florida, USA.
- Dominey, W. J.** 1983. Mobbing in colonially nesting fishes, especially the bluegill *Lepomis macrochirus*. *Copeia* 1983: 1086–1088. <https://doi.org/10.2307/1445113>
- Ernst, C. H., and J. E. Lovich.** 2009. *Turtles of the United States and Canada*. Johns Hopkins University Press, Baltimore, Maryland, USA.
- Harper, C. A., and E. G. Bolen.** 1996. Duckweed (Lemnaceae) as habitat for macroinvertebrates in eastern North Carolina. *Wetlands* 16: 240–244. <https://doi.org/10.1007/BF03160697>
- Herrel, A., J. C. O’Reilly, and A. M. Richmond.** 2002. Evolution of bite performance in turtles. *Journal of Evolutionary Biology* 15: 1083–1094. <https://doi.org/10.1046/j.1420-9101.2002.00459.x>
- Jastrebski, C. J., and B. W. Robinson.** 2004. Natural selection and the evolution of replicated trophic polymorphisms in Pumpkinseed Sunfish (*Lepomis gibbosus*). *Evolutionary Ecology Research* 6: 285–305.
- Kadlec, J. A.** 1962. Effects of drawdown on a waterfowl impoundment. *Ecology* 43: 267–281. <https://doi.org/10.2307/1931982>
- Lagler, K. F.** 1943. Food habits and economic relations of the turtles of Michigan with special reference to fish management. *American Midland Naturalist* 29: 257–312. <https://doi.org/10.2307/2420793>
- Lauder, G. V., and T. Prendergrast.** 1992. Kinematics of aquatic prey capture in the Snapping Turtle *Chelydra serpentina*. *Journal of Experimental Biology* 164: 55–78.
- Lawrence, D., and S. L. Peterson.** 2010. Common Snapping Turtle preys on an adult Western Grebe. *Waterbirds* 33: 105–109. <https://doi.org/10.1675/063.033.0113>
- Moldowan, P. D., M. G. Keevil, P. B. Mills, R. J. Brooks, and J. D. Litzgus.** 2015. Diet and feeding behaviour of Snapping Turtles (*Chelydra serpentina*) and Midland Painted Turtles (*Chrysemys picta marginata*) in Algonquin Provincial Park, Ontario. *Canadian Field-Naturalist* 129: 403–408. <https://doi.org/10.22621/cfn.v129i4.1764>
- Pettit, K. E., C. A. Bishop, and R. J. Brooks.** 1995. Home range and movements of the common Snapping Turtle *Chelydra serpentina serpentina*, in a coastal wetland of Hamilton Harbor, Lake Ontario, Canada. *Canadian Field-Naturalist* 109: 192–200. Accessed 22 December 2017. <https://www.biodiversitylibrary.org/item/109902#page/204/mode/1up>.
- Punzo, F.** 1975. Studies on the feeding behavior, diet, nesting habits and temperature relationships of *Chelydra serpentina* Osceola (Chelonia: Chelydridae). *Journal of Herpetology* 9: 207–210. <https://doi.org/10.2307/1563038>
- Ratz, H., H. Moller, and D. Fletcher.** 1999. Predator identification from bite marks on Penguin and Albatross chicks. *Marine Ornithology* 27: 149–156.
- Schneider, J. C.** 1998. Fate of dead fish in a small lake. *American Midland Naturalist* 140: 192–196. [https://doi.org/10.1674/0003-0031\(1998\)140\[0192:FODFIA\]2.0.CO;2](https://doi.org/10.1674/0003-0031(1998)140[0192:FODFIA]2.0.CO;2)
- Scott, W. B., and E. J. Crossman.** 1998. *Freshwater Fishes of Canada*. Galt House, Oakville, Ontario, Canada.

Spotila, J. R., and B. A. Bell. 2008. Thermal ecology and feeding of the Snapping Turtle, *Chelydra serpentina*. Pages 71–79 in *Biology of the Snapping Turtle (Chelydra serpentina)*. Edited by A. C. Steyermark, M. S. Finkler, and R. J. Brooks. Johns Hopkins University Press, Baltimore, Maryland, USA.

Summers, A. P., K. F. Darouian, A. M. Richmond, and E. L. Brainerd. 1998. Kinematics of aquatic and terrestrial prey capture in *Terrapene carolina*, with implications for the evolution of feeding in Cryptodire turtles. *Journal of Experimental Zoology Part A* 281: 280–287. [https://doi.org/10.1002/\(SICI\)1097-010X\(19980701\)281:4%3C280::AID-JEZ4%3E3.0.CO;2-K](https://doi.org/10.1002/(SICI)1097-010X(19980701)281:4%3C280::AID-JEZ4%3E3.0.CO;2-K)

Van Devender, T. R., and N. T. Tessman. 1975. Late Pleistocene snapping turtles (*Chelydra serpentina*) from southern Nevada. *Copeia* 2: 249–253. <https://doi.org/10.2307/1442882>

Vervust, B., J. Brecko, and A. Herrel. 2011. Temperature effects on snapping performance in the common snapper *Chelydra serpentina* (Reptilia, Testudines). *Journal of Experimental Zoology* 315: 41–47. <https://doi.org/10.1002/jez.650>

Wainwright, P. C., L. A. Ferry-Graham, T. B. Waltzek, A. M. Carroll, C. D. Hulsey, and J. R. Grubich. 2001. Evaluating the use of ram and suction during prey capture by cichlid fishes. *Journal of Experimental Biology* 204: 3039–3051.

Received 19 September 2016
Accepted 5 September 2017

SUPPLEMENTARY MATERIAL:

VIDEO S1. A mature Snapping Turtle (*Chelydra serpentina*) inspects a Pumpkinseed (*Lepomis gibbosus*) nest in the littoral habitat of Ashby Lake (Addington Highlands region, Ontario, Canada) where it apparently feeds on goldeneye-stage sunfish larvae. https://www.youtube.com/watch?v=gNOVM30q_Cc.

Range Extensions of 35 Bryophyte Species in the Black Spruce–Feather Moss Forest of Western Quebec, Canada

MARION BARBÉ^{1, 4}, LOUIS DUBOIS², JEAN FAUBERT³, MARTIN LAVOIE², YVES BERGERON¹, and NICOLE J. FENTON¹

¹Université du Québec en Abitibi-Témiscamingue, Institut de recherche sur les forêts, 445, boul. de l'Université, Rouyn-Noranda, Québec J9X 4E5 Canada

²Université Laval, Département de géographie, 2405, rue de la Terrasse, Québec, Québec G1V 0A6 Canada

³Société québécoise de bryologie, 47, 4^{ème} Rang Est, Saint-Valérien-de-Rimouski, Québec G0L 4E0 Canada

⁴Corresponding author: marion.barbe@uqat.ca

Barbé, Marion, Louis Dubois, Jean Faubert, Martin Lavoie, Yves Bergeron, and Nicole J. Fenton. 2017. Range extensions of 35 bryophyte species in the Black Spruce–feather moss forest of western Quebec, Canada. *Canadian Field-Naturalist* 131(3): 258–269. <https://doi.org/10.22621/cfn.v131i3.1901>

Although the North American bryophyte flora are relatively well known, bryophytes of the Black Spruce–feather moss forest in the Nord-du-Québec administrative region, especially its southern portion (49–51°N, 74–79°W), remain under-sampled. Here, we report 169 bryophyte taxa for this region, of which 35 (14 true mosses, 20 liverworts, one sphagnum) represent noteworthy records, including 20 taxa new for the region. These new occurrences close several gaps in distribution in the study area and, more broadly, in the boreal Black Spruce (*Picea mariana*) forest of adjacent Ontario. Microhabitat preferences of the species are also documented. This work represents a substantial contribution to knowledge of the bryophyte flora, which will help refine protection priority ranks of species of Quebec and Labrador.

Key Words: Boreal forest; bryoflora; bryo-geography; liverwort; true moss; sphagna; northern Quebec

Malgré une bonne connaissance globale de la bryoflore nord-américaine, la pessière noire à mousses de certaines régions telles que le Nord-du-Québec et notamment sa partie méridionale (49–51°N, 74–79°W) demeure sous-échantillonnée. Nous rapportons 169 taxons bryophytiques dans cette région, dont 35 (14 mousses, 20 hépatiques et une sphaigne) représentent des ajouts substantiels à la flore, incluant même 20 nouveaux taxons pour le territoire considéré. Ces récoltes permettent de relier les aires de répartition jusque-là disjointes de plusieurs taxons en pessière noire à mousses au Québec, mais aussi dans la province adjacente de l'Ontario. Les préférences des espèces en termes de microhabitats sont aussi décrites. Ce travail contribue à améliorer les connaissances sur la bryoflore et permettra de redéfinir les rangs de priorité pour la conservation des espèces au Québec et Labrador.

Mots-clés: aire de répartition; bryoflore; forêt boréale; hépatiques; mousses; sphaignes; Nord-du-Québec

Introduction

Bryophytes (liverworts, true mosses, and sphagna), along with lichens, dominate the coniferous boreal forest in terms of biomass, species richness (Turetsky *et al.* 2012), and net primary productivity (Bisbee *et al.* 2001; Proctor 2011). They form a continuous carpet several centimetres thick and inhabit a variety of microhabitats (Dynesius and Hylander 2007). Bryophytes represent 25% of the plant diversity of Quebec (Faubert *et al.* 2010). In 2016, the database of the bryophytes of Quebec–Labrador listed 231 species of liverworts, 582 species of mosses, and 62 species of *Sphagnum* (Faubert *et al.* 2014+). However, the distributional ranges of some species are only partly defined, and the bryophyte flora is unknown in certain areas (Faubert and Gagnon 2013).

This is the case for the administrative region of Abitibi-Témiscamingue and the adjacent southern portion of the Nord-du-Québec administrative region, which have been neglected in terms of bryophyte sampling compared with other regions. Understanding the frequency and distribution of species is of primary importance in establishing conservation plans and in implementing resource management practices in these regions, where boreal forests are disturbed both by nat-

ural wildfires and anthropogenic exploitation (forest harvest, mining, hydroelectric development). These cumulative disturbances of the landscape threaten species that are ill-adapted to anthropogenic environments, including many bryophytes (Fenton and Frego 2005; Hylander *et al.* 2005; Caners *et al.* 2013).

Since the publication of the Catalogue des bryophytes du Québec et du Labrador (Faubert 2007), the number of bryophyte species documented in Quebec and Labrador has continued to grow (Gauthier 2011; Moisan and Pellerin 2011; Faubert *et al.* 2012; Faubert and Gagnon 2013). New occurrences are continuously being compiled in the online database of the bryophytes of Quebec–Labrador (Faubert *et al.* 2014+), contributing to continuous updating of the bryophyte flora (Faubert 2012–2014). The current study contributes to our understanding of bryophyte distributional ranges at the scale of the boreal Black Spruce (*Picea mariana* (Miller) Britton, Sterns & Poggenburgh) forest of Quebec–Labrador. We describe the bryophyte community of this forest bioclimatic domain, including microhabitat preferences, which may permit better forest development practices and bryophyte conservation.

Study Area

The study area covers 73 197 km² (48°83'N to 50°71'N and 74°50'W to 79°69'W) in the southern portion of the Nord-du-Québec administrative region of western Quebec (Figure 1). After the retreat of the Laurentide Ice Sheet, the area was covered by the proglacial lakes Barlow and Ojibway, which existed 11 500 and 7900 radio carbon years before present, respectively (Vincent and Hardy 1977). Sedimentation in the lakes generated a layer of clay 10–60 m thick that forms the soils of the “clay belt” of northeastern Ontario and northwestern Quebec. There is little topographic variation in the region, with elevations ranging from 200 to 300 m above sea level.

The study area is located in the Black Spruce–feather moss forest bioclimatic domain that extends over 154 184 km² in Quebec (Grondin 1996). Forest stands are dominated by Black Spruce, Jack Pine (*Pinus banksiana* Lambert), Trembling Aspen (*Populus tremuloides* Michaux), Balsam Fir (*Abies balsamea* (L.) Mill.), and Paper Birch (*Betula papyrifera* Marshall). The understorey is dominated by ericaceous shrubs on a ground cover of bryophytes (Saucier *et al.* 2009). The natural dynamics of these forests are driven primarily by stand-replacing wildfires. The fire cycle has been estimated at 398 years (Bergeron *et al.* 2004), and the average age of the forest is over 150 years. Average annual temperature and precipitation (1981–2010) are 1°C and 928 mm.

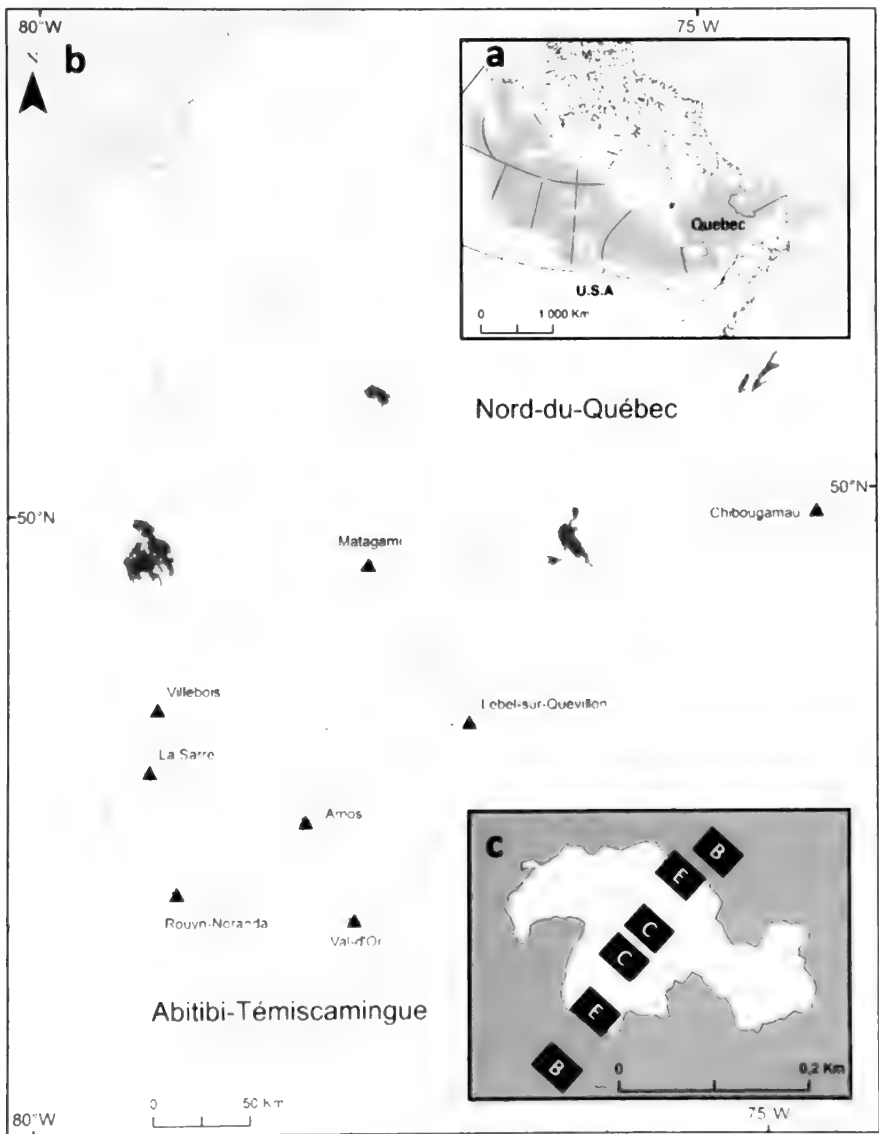


FIGURE 1. a. Location of the study area (white square) in the Nord-du-Québec administrative region of western Quebec, Canada, within the boreal Black Spruce (*Picea mariana*) forest bioclimatic domain (dark grey). b. The six wildfires sampled (dark grey shapes) in Black Spruce forest bioclimatic domain (light grey zone; adapted from Payette and Bouchard 2001). Triangles represent main cities. c. Black rectangles represent sample plots of 50 m² located along a transect crossing the residual patch (light grey) from burned area (B) to edge (E) and core (C).

respectively (Environment Canada 2017). The region is characterized by long winters, with 313 cm of snowfall annually, and a short growing season of 140–160 days.

Methods

Bryophyte Sampling

Bryophytes were sampled within the footprints of six natural wildfires (Figure 1b) varying in age, size, and origin and used for a study on post-fire residual forest patches (Barbé *et al.* 2016, 2017). Within each wildfire footprint, we identified five residual patches (unburned forest areas) and three burned areas for a total of 30 residual patches aged 36–3400 years (time since last wildfire) and 18 burned matrices aged 10–44 years (time since last wildfire). The age of the patches was estimated by coring 10 dominant trees; if the 10 dominant trees were approaching their maximum lifespan (> 180 years old for Black Spruce; Simard *et al.* 2007) the age of the patch was determined by ^{14}C dating of charcoal particles extracted from the mineral soil. Age of burned areas corresponds to time since the last fire determined from Société de protection des forêts contre le feu digital maps (SOPFEU 2011). All residual patches were chosen based on the following criteria: Black Spruce dominance, accessibility (< 600 m from the logging road), flat topography, and no complete submergence of the soil except in local depressions (water-holes). No bogs or fens were sampled, but post-fire residual patches located in paludified (i.e., natural succession to peatland; Crawford *et al.* 2003) Black Spruce forests were included. Consequently, we sampled sites encompassing the range of natural Black Spruce forest succession: from recently burned to paludified areas. Patches varied in size (0.05–11.1 ha) and forest structure (e.g., 7.4–109 m³/ha of coarse woody debris). More details about the characteristics of the patches are presented in Barbé *et al.* (2017).

Rectangular plots (50 m²) were used to sample the bryophyte communities in each residual patch and burned area. At each location, a north–south linear transect was established that included the burned zone, edge, and core positions (Figure 1c). In patches smaller than 1 ha, five plots were placed along the transect: two in the surrounding burned zone, two straddling each edge of the patch, and one in the core. In patches over 1 ha, a second core plot was added. Plots were 10–200 m apart. In each wildfire footprint, three additional 50-m² plots of burned area were placed 200–850 m from residual patches. Size, number, orientation, and placement of sampling plots were chosen to include all microhabitats at each site, from more humid and cold microhabitats found at the northern edge and in residual patch cores, to warmer and drier microhabitats found at the southern edge and in burned areas. In total, the bryophyte community was sampled over 9300 m²: 108 plots in 30 residual patches (48 cores and 60 edges) and 78 plots in burned areas (2 × 30 residual patches plus 3 × 6 wildfires). The four corners of each plot were geo-

located using a handheld global positioning system receiver (Garmin GPSmap 62, Olathe, Kansas, USA).

In each 50-m² plot, the bryophyte community was sampled using a modified form of “floristic habitat sampling” (Newmaster *et al.* 2005), which consists of sampling all the bryophytes present in all microhabitats (e.g., coarse woody debris, tree bases, peat mounds, water holes). This method was used to ensure that all small non-visible species were captured. Vouchers of all specimens are stored at the Université du Québec en Abitibi-Témiscamingue (Rouyn-Noranda, Canada). Nomenclature follows Faubert *et al.* (2014+) except for *Sphagnum subtile* (Russ.) Warnst. (Flora of North America Editorial Committee 2007).

All samples were dried and later identified to species level using a stereomicroscope and a compound light microscope following the specimen preparation and identification method described in Faubert (2012). Damaged, senescent, or immature specimens were identified only to genus level. The microhabitat in which each species was found was qualitatively compared with data from Flore des Bryophytes du Québec–Labrador (Faubert 2012–2014; herein shortened as “Flora”) to determine whether a species was specific to certain microhabitats in the study area.

Distribution Maps

Provincial distribution maps were generated for species found in this study whose ranges differed from those previously known in Quebec. New occurrences were compared with those detailed in the open-access BRYOQUEL participative online database of the bryophytes of Quebec–Labrador (Faubert *et al.* 2014+). New occurrences were also compared with documented occurrences from the neighbouring province of Ontario (Ireland and Ley 1992; Ley and Crowe 1999; CNALH 2017). Maps were generated using the geographic information system, ArcGis 10.3.1 (Environmental Systems Research Institute [ESRI], Redlands, California, USA). Original map layers were from the GéoIndex+ platform of the Geographic and Statistic Information Centre (GéoStat Centre) of the Université Laval created with data from Statistics Canada, geographic division, DMTI Spatial Inc. (Richmond Hill, Ontario, Canada), and ESRI. The projection used for all maps was NAD83 CSRS MTM 10.

Data Analyses

Provincial occurrences, extracted from Faubert *et al.* (2014+), are “previously documented occurrences” and were classified into four categories: rare (< 5 occurrences), infrequent (5–10), uncommon (11–30), and common (> 30; Table 1). There was no minimum distance between occurrences. The local occurrences from this study were treated as “new occurrences”. Local occurrences refer to the record of one species in a residual patch or a burned area. Indeed, even though a species was found several times in the same residual patch or burned area (i.e., several records in the same 50-m²

plot), only one occurrence was drawn on the map (one cross) to avoid overloading maps with superimposed crosses. Local occurrences followed the same categories as provincial ones but were based on the number of plots where the species was found: rare (recorded in < 5 plots), infrequent (5–10 plots), uncommon (11–30 plots), and common (> 30 plots). Local occurrences were used to refine species occurrences in Quebec. For example, a species represented by 28 provincial occurrences plus 10 new local occurrences was updated from uncommon to common in Quebec. Each occurrence (provincial as well as local) was presented regardless of plot and site location. Species were grouped by their provincial and local occurrences: group 1: locally uncommon/infrequent species already recorded near the study area; group 2: provincially common to rare species only recorded sporadically near the study area; group 3: species that were new occurrences for the study area.

Microhabitats of species in the study area were compared with those documented in Flora (Faubert 2012–2014), which were compiled from an exhaustive list of preferential microhabitats found in the literature (Schuster 1966–1992; Crum and Anderson 1981; Ireland 1982) plus additional microhabitats from specimens collected in Quebec. Thus, we compared species' microhabitat preferences between boreal Black Spruce forest and habitats in the rest of the province and the species' Canadian distribution to identify differences in microhabitat preferences in the Black Spruce forest of western Quebec. Microhabitats were classified as humus (T: terricolous species living on soil and litter), peat (B: species living among sphagna or on exposed peat in paludified areas), dead wood (DW: facultative or obligate epixylics), epiphyte (EP: epiphytic or corticolous species on living trees and shrubs), and rock (R: saxicolous species).

Results

Bryophyte Community and Species Distribution

Bryophytes were sampled in 11 036 microhabitats, each containing on average four species (range 0–20) for a total of 169 species encountered (61 liverworts, 90 mosses, and 18 sphagna; Appendix S1). Locally, 118 species (70% of all species) were common (found in more than 30 plots); the remaining species occurred more sporadically over the sampling area.

Post-fire residual patches were dominated by the feather mosses, *Hylocomium splendens* (Hedw.) Schimp., *Pleurozium schreberi* (Willd. ex Brid.) Mitt., and *Ptilidium crista-castrensis* (Hedw.) De Not., with frequent occurrences of the acrocarp species, *Dicranum fuscescens* Turner and *Polytrichum commune* Hedw. var. *commune*, and of the liverworts, *Lophozia ventricosa* (Dicks.) Dumort., *Ptilidium ciliare* (L.) Hampe, and *Ptilidium pulcherrimum* (Weber) Hampe. The wettest sites also supported *Aulacomnium palustre* (Hedw.) Schwägr., *Sanionia uncinata* (Hedw.) Loeske, and *Warnstorfia*

TABLE 1. The 35 species of bryophytes with range extensions in the south of the Nord-du-Québec administrative region, western Quebec, Canada. Significant additions to the flora of Quebec-Labrador are bolded. Species group affiliations are: 1, locally uncommon/infrequent already recorded near the study area; 2, provincially common to rare only recorded sporadically near the study area; and 3, new occurrences for the study area.

	Species group affiliation	Previously documented Quebec occurrences*	New occurrences	Status in Quebec-Labrador and proposed change (→)	Proposed modification to range†	Closest known Quebec occurrence (km)	Factors possibly explaining Quebec modification of distributional ranges		Microhabitats‡	
									Previously documented	Newly observed
Mosses										
<i>Brachythecium erythrorhizon</i>	2	25	4	Uncommon	—	115			T R	DW
<i>Brachythecium starkei</i>	2	13	92	Uncommon → common	—	110	ID confusion		T	C DW
<i>Campylium protensum</i>	3	19	19	Rare → uncommon	Extended west	605	ID confusion		W	C DW
<i>Dicranum fulvum</i>	3	Cont. dist.	3	Common	Extended north	135			R	DW
<i>Helodium blandowii</i> var. <i>blandowii</i>	3	Cont. dist.	3	Common	Extended west	325			P	C T
<i>Hypnum curvifolium</i>	3	Cont. dist.	2	Common	Extended west	270			N/A	DW
<i>Hypnum lauriei</i>	3		1	?			ID confusion		C DW R T	DW
<i>Isoperigopsis muelleriana</i>	3	32	9	Common		100			R	DW
<i>Isoperigopsis pulchella</i>	3	48	3	Common	Extended west	550			C DW R T	
<i>Pohlia elongata</i> var. <i>elongata</i>	3	20	2	Uncommon	Extended west	260			N/A	I
<i>Pohlia sphagnicola</i>	3	18	634	Uncommon → common		300	ID confusion		P	C F P T
<i>Polytrichum commune</i> var. <i>perigranide</i>	3	25	12	Uncommon	Extended west	60			T	C

TABLE 1. (continued)

Species group affiliation	Previously documented Quebec occurrences*	New occurrences	Status in Quebec-Labrador and proposed change (→)	Proposed modification to range†	Closest known Quebec occurrence (km)	Factors possibly explaining modification of distributional ranges		Microhabitats‡	
								Previously documented	Newly observed
<i>Thuidium recognitum</i>	Cont. dist.	5	Common	Extended north	75			C/DW/R	
<i>Uloa crispata</i>	Cont. dist.	16	Common		165			C	DW/T
LIVERWORTS									
<i>Calypogeia sphagnicola</i>	12	151	Uncommon → common	BBSF?	25			P	C/DW/R/T
<i>Calypogeia suecica</i>	15	6	Uncommon	Extended west	300	< 2 mm		C	
<i>Cephalozia elachista</i>	10	20	Infrequent → uncommon	—	365	< 0.5 mm		P	C/DW/T
<i>Cephalozia hampeana</i>	16	56	Uncommon → common	—	20	Under sampled		P/DW/R	C/T
<i>Cephalozia spinigera</i>	10	10	Infrequent	—	360	Under sampled		P	C/DW/T
<i>Chiloscyphus coadunatus</i> var. <i>rivularis</i>	17	29	Rare → uncommon	—	550	Under sampled		R	C/DW
<i>Fuscocephalozia loitlesbergeri</i>	10	100	Infrequent → common	—	490	0.6–0.8 mm		P	C/DW/T
<i>Fuscocephalozia pleniceps</i>	29	219	Uncommon → common	BBSF?	25	Under sampled		P/DW	C/R
<i>Kurzia pauciflora</i>	18	3	Uncommon	—	65	Under sampled		P	DW/T
<i>Lophozia ascendens</i>	30	20	Uncommon	—	35	0.8–1.3 mm		DW	C
<i>Lophozia bicrenata</i>	25	14	Uncommon	—	45	Under sampled		T	DW/R
<i>Lophozia guttulata</i>	21	82	Uncommon → common	BBSF?	27	1–1.8 mm		P/DW	C/R/T
<i>Lophozia silvicola</i>	3	77	Infrequent → common	Extended west	350	ID confusion		DW/R	C/P/T
<i>Mesoptychia heterocolpos</i> var. <i>heterocolpos</i>	67	2	Common	—	670			DW/R	
<i>Mesoptychia ruhheana</i>	15	1	Uncommon	—	450	3–5 mm		P	
<i>Odontoschisma francisci</i>	18	19	Rare → uncommon	—	80			P/T	C/DW
<i>Scapania apiculata</i>	6	3	Infrequent	Extended northwest	360			DW	P
<i>Scapania uliginosa</i>	9	1	Infrequent	Extended west	465	< 4 mm		R	
<i>Schistochloopsis laxa</i>	3	2	Rare	—	35	1.5–2 mm		P	T
<i>Sphenolobus hellerianus</i>	38	92	Uncommon → common	BBSF?	26	< 1 mm		DW	C
						Under sampled			
SPHAGNUM									
<i>Sphagnum tenerum</i>	7	29	Infrequent → uncommon		350	ID confusion		NA	P/DW/R/T

Note: Cont. dist. = continuous distribution, ID = identification, BBSF = boreal Black Spruce forest.
*From Faubert *et al.* (2014+).
†No proposed modification suggests that the new occurrences are too few to extend species distribution. BBSF? = may extend to the whole boreal Black Spruce forest bioclimatic domain in the Quebec-Labrador (based on vegetation zones defined by Payette and Bouchard 2001).
‡Microhabitats previously documented from Faubert (2012–2014); empty boxes indicate that no additional microhabitats were found: C = epiphytic or corticolous; DW = dead wood; NS = not specified; P = peat; R = rock; T = terricolous; W = wet.
§This species was misidentified as *Hypnum fertile*, absent in Quebec Labrador; therefore, presenting a map is impossible without revision of the herbarium specimens.

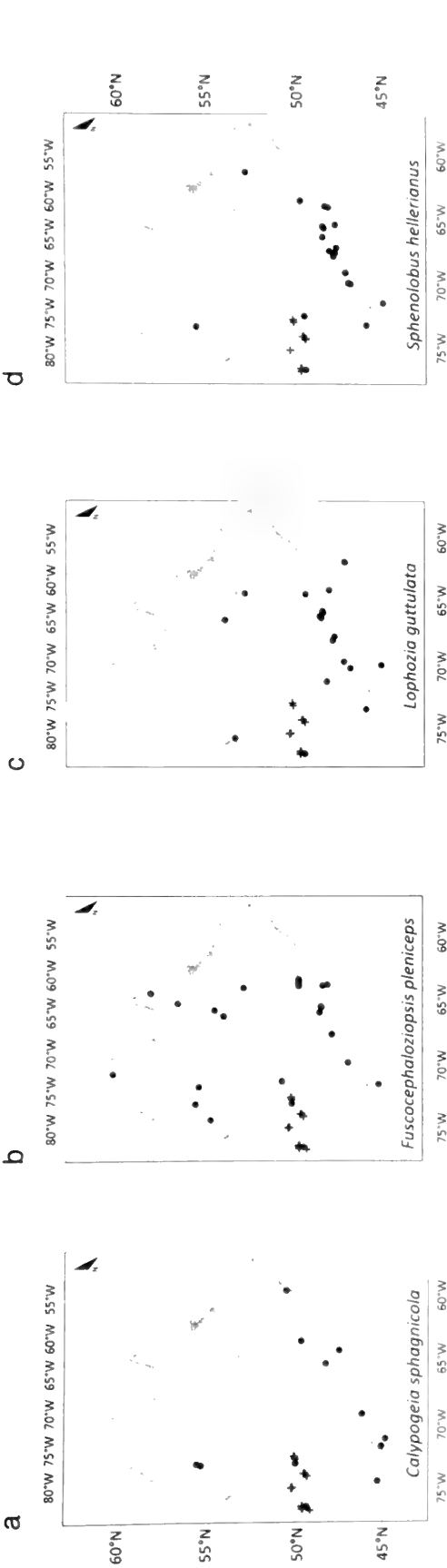


FIGURE 2. Distributional ranges of the four species of group 1, comprising provincially uncommon or infrequent species previously recorded 26–32 km from the study area: a. *Calypogeia sphagnicola*, b. *Fuscocephaloziopsis pleniceps*, c. *Lophozia guttulata*, d. *Sphenolobus hellerianus*. Dots show previously documented occurrences; plus signs are new occurrences. The shaded area represents the boreal Black Spruce feather moss forest where the species likely occur.

fluitans (Hedw.) Loeske, whereas *Ceratodon purpureus* (Hedw.) Brid., *Polytrichum juniperinum* Hedw., and *Pohlia nutans* (Hedw.) Lindb. were found mainly in burned areas, which were also the driest sites. In addition, deep mats of sphagna (*Sphagnum capillifolium* (Ehrh.) Hedw., *Sphagnum fallax* H. Klinggr., *Sphagnum magellanicum* Brid.) were found, as many of the sites sampled were undergoing paludification (Fenton *et al.* 2005). Some of the species described as common in the coniferous boreal forests of Quebec in Faubert (2012–2014) were under-represented (≤ 15 occurrences) in our samples (e.g., *Barbilophozia hatcheri* (A. Evans) Loeske, *Bryum capillare* Hedw., *Tomenthypnum nitens* (Hedw.) Loeske).

In addition to these locally common species, 35 species (14 true mosses, 20 liverworts, and one sphagnum) represent noteworthy records (Table 1). Of these, four species (group 1) were locally uncommon or infrequent, but were expected to be found because they have already been recorded 25 km from the study area in Quebec and 50–150 km from the study area in Ontario: *Calypogeia sphagnicola* (Arnell & J. Perss.) Warnst. & Loeske, *Fuscocephaloziopsis pleniceps* (Austin) Vána & L. Söderstr., *Lophozia guttulata* (Lindb. & Arnell) A. Evans, and *Sphenolobus hellerianus* (Nees ex Lindenb.) Steph. (Figure 2). Ten other species (group 2), including four true mosses (*Brachythecium erythrorrhizon* Schimp., *B. starkei*, (Brid.) Schimp., *Isopterygiopsis muelleriana* (Schimp.) Z. Iwats., *Polytrichum commune* Hedw. var. *perigoniale* (Michx.) Hampe and six liverworts (*Cephaloziella hampeana* (Nees) Schiffn. ex Loeske, *Kurzia pauciflora* (Dicks.) Grolle, *Lophozia ascendens* (Warnst.) R.M. Schust., *L. bicrenata* (Schmidel) Dumort., *Odontoschisma francisci* (Hook.) L. Söderstr. & Vána, *Schistochloopsis laxa* (Lindb.) Konstant.) were provincially common to rare, but had been recorded only sporadically near the study area (one to three occurrences 20–115 km; Figure 3). Some of these moss species are found west of the study area, in Ontario (i.e., *Brachythecium erythrorrhizon*, *B. starkei*, *Polytrichum commune* var. *perigoniale*), where they have already been recorded 50–200 km from the provincial border (Ireland and Ley 1992; Ley and Crowe 1999; CNALH 2017).

Finally, 20 species (group 3) are new occurrences for the study area, with range extensions from 75 km to more than 670 km in Quebec–Labrador. These include nine true mosses (*Campylium protensum* (Brid.) Kindb., *Dicranum fulvum* Hook., *Helodium blandowii* (E. Weber & D. Mohr) Warnst. var. *blandowii*, *Hypnum curvifolium* Hedw., *Isopterygiopsis pulchella* (Hedw.) Z. Iwats., *Pohlia elongata* Hedw. var. *elongata*, *P. sphagnicola* (Bruch & Schimp.) Broth., *Thuidium recognitum* (Hedw.) Lindb., *Ulotia crispa* (Hedw.) Brid.), 10 liverworts (*Calypogeia suecica* (Arnell & J. Perss.) Müll. Frib., *Cephaloziella elachista* (J.B. Jack) Schiffn., *C. spinigera* (Lindb.) Jörg., *Chiloscyphus coadunatus* (Sw.) R.M. Schust. & J.J. Engel var. *rivularis* (Raddi)

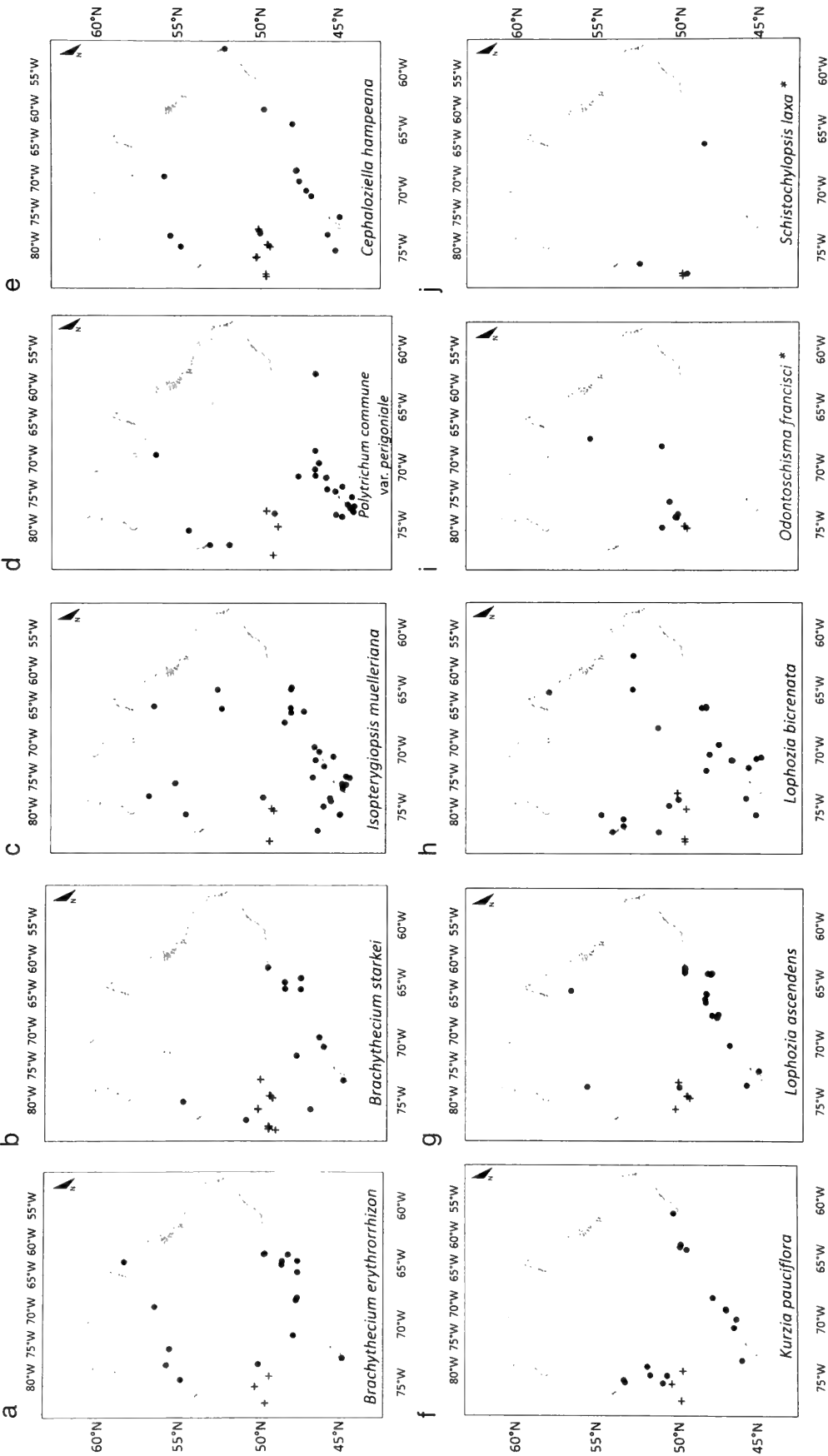


FIGURE 3. Distributional ranges of species of group 2 (10 in total), comprising provincially common to rare species sporadically recorded in the study area previously: a. *Brachythecium erythrorhizon*, b. *Brachythecium starkei*, c. *Isopterygiopsis muelleriana*, d. *Polytrichum commune* var. *perigoniale*, e. *Cephalozia hampeana*, f. *Kurzia pauciflora*, g. *Lophozia ascendens*, h. *Lophozia bicrenata*, i. *Odontoschisma francisci*, j. *Schistochyloopsis laxa*. Their presence in the study area was confirmed by numerous newly reported occurrences. Dots show previously documented occurrences; plus signs are new occurrences. The shaded zone represents the boreal Black Spruce feather moss forest in cases where the new occurrences suggest that the species may be found throughout the whole bioclimatic domain. Asterisks indicate species that are provincially rare according to Faubert *et al.* (2014+).

Frisvoll, Elvebakk, Flatberg & Okland, *Fuscocephaloziopsis loitlesbergeri* (Schiffn.) Vána & L. Söderstr., *Lophozia silvicola* H. Buch, *Mesoptychia heterocolpos* (Thed. ex Hartm.) L. Söderstr. & Vána var. *heterocolpos*, *Mesoptychia rutheana* (Limpr.) L. Söderstr. & Vána, *Scapania apiculata* Spruce, *S. uliginosa* (Lindenb.) Dumort.), and one sphagnum (*Sphagnum tenerum* Sull. & Lesq. ex Sull.; Figure 4). Considering occurrences from Ontario, we report a 50–200 km eastward extension of the distributional range of *Helodium blandowii* var. *blandowii*, *Isopterigiopsis pulchella*, *Pohlia sphagnicola*, and *Thuidium recognitum* (Ireland and Ley 1992; CNALH 2017).

Hypnum fauriei Cardot was sampled once in the study area. No map was produced for this species because its distribution in the province is unknown as a result of its recent separation from *H. fertile* Sendtn. (Faubert 2014).

Bryophyte Microhabitat Preferences

The microhabitat preferences of the 35 species discussed above were more diverse than reported previously in Flora (Faubert 2012–2014; Table 1). For example, two mosses (*Pohlia sphagnicola* and *Calypogeia sphagnicola*) and several liverworts were found in a greater variety of microhabitats than the exclusive peat microhabitat mentioned in Flora (Faubert 2012–2014). Eighteen species were recorded on tree or shrub bases in Black Spruce forest, especially *Picea mariana* and *Rhododendron groenlandicum* (Oeder) Kron & Judd (Table 1), although they were not described as corticolous or epiphytic at the provincial scale. Half were associated with only one tree or shrub species, but multiple hosts were also identified for many bryophyte species (e.g., *Pohlia sphagnicola*, *Brachythecium starkei*, *Cephaloziella elachista*; data not shown). Similarly, numerous species not previously identified as epixylics in Flora (Faubert 2012–2014) were found on dead wood (Table 1; e.g., *Brachythecium erythrorrhizon*, *Dicranum fulvum*).

Discussion

Among the 169 bryophytes species identified, we have documented 20 new species for the study area and increased the understanding of the distributional range for 15 others. Our results suggest that these species may be more common in Quebec–Labrador and especially in the bioclimatic domain of the Black Spruce-feather moss forest, than previous occurrences indicate. We examine here the noteworthy occurrences within groups 1, 2, and 3 as identified above.

Distributional Ranges Extended to the Entire Boreal Black Spruce Forest Bioclimatic Domain

Even though already documented in the study area, we extended the known distribution of four species of liverwort (*Calypogeia sphagnicola*, *Fuscocephaloziopsis pleniceps*, *Lophozia guttulata*, and *Sphenolobus hellerianus*), with 82 to more than 200 new occurrences

for these species. These occurrences, together with those already documented from eastern Quebec, suggest their continuous distributional ranges extend throughout the Black Spruce forest of Quebec–Labrador. Furthermore, the dispersed and numerous locations of these species indicate that they are common but under-sampled in the province. Further extension of their continuous distributional ranges to all of Quebec–Labrador may be possible, but more sampling is needed to determine their true distributions.

Our results also extend to the entire Black Spruce forest domain the known distributions of the liverworts *Cephaloziella elachista*, *C. hampeana*, *C. spinigera*, *Chiloscyphus coadnatus* var. *rivularis*, *Fuscocephaloziopsis loitlesbergeri*, *Kurzia pauciflora*, and *Odontoschisma francisci*, and of the true mosses *Brachythecium starkei* and *Pohlia sphagnicola*. However, some of them (*Cephaloziella elachista*, *C. spinigera*, *Chiloscyphus coadnatus* var. *rivularis*, *F. loitlesbergeri*, *Lophozia silvicola*, and *O. francisci*) have only rarely been recorded in eastern Quebec; further sampling is needed to confirm their presence across the province. In light of the 92 and 56 new occurrences of *B. starkei* and *C. hampeana*, respectively, as well as the 634 new occurrences of *P. sphagnicola*, the status of these species in the province should be changed from uncommon to common. Liverworts, especially Cephaloziellaceae and *K. pauciflora*, are minute (< 1 mm wide shoots) and especially difficult to detect, which has probably contributed to the underestimation of their frequency and distribution. Directed sampling efforts focusing on these taxa might help distinguish between a lack of sampling versus true rarity in other regions. The distributional ranges of the true mosses *B. starkei* and *P. sphagnicola* are unclear because of past misidentifications (Faubert 2012–2014). Indeed, in the past, the few and confusing diagnostic characters discriminating these species from others of the same genera have led to confusion between *B. starkei* and *B. curtum* (Lindb.) Limpr., *P. sphagnicola* and *P. nutans*, and between *Sphagnum tenerum* and *S. capillifolium*.

Lophozia bicrenata also needs attention. This uncommon and minute species, typical of disturbed landscapes, is present in dispersed locations across the entire province. It is possible that this species is found province-wide, but this possibility can only be addressed by additional sampling to discriminate between true rarity and under-collection.

Distributional Ranges Extended to the North and West

The few new reported occurrences of *Dicranum fulvum* and *Thuidium recognitum* (three and five, respectively) extend the provincial distribution of these species 135 km to the north and 75 km to the west, respectively. These species are common in the province, but have not been previously recorded in the study area. *Helodium blandowii* var. *blandowii*, *Hypnum curvifolium*, and *Uloa crispa* are also common. However, we do not suggest extension of their continuous distributions be-

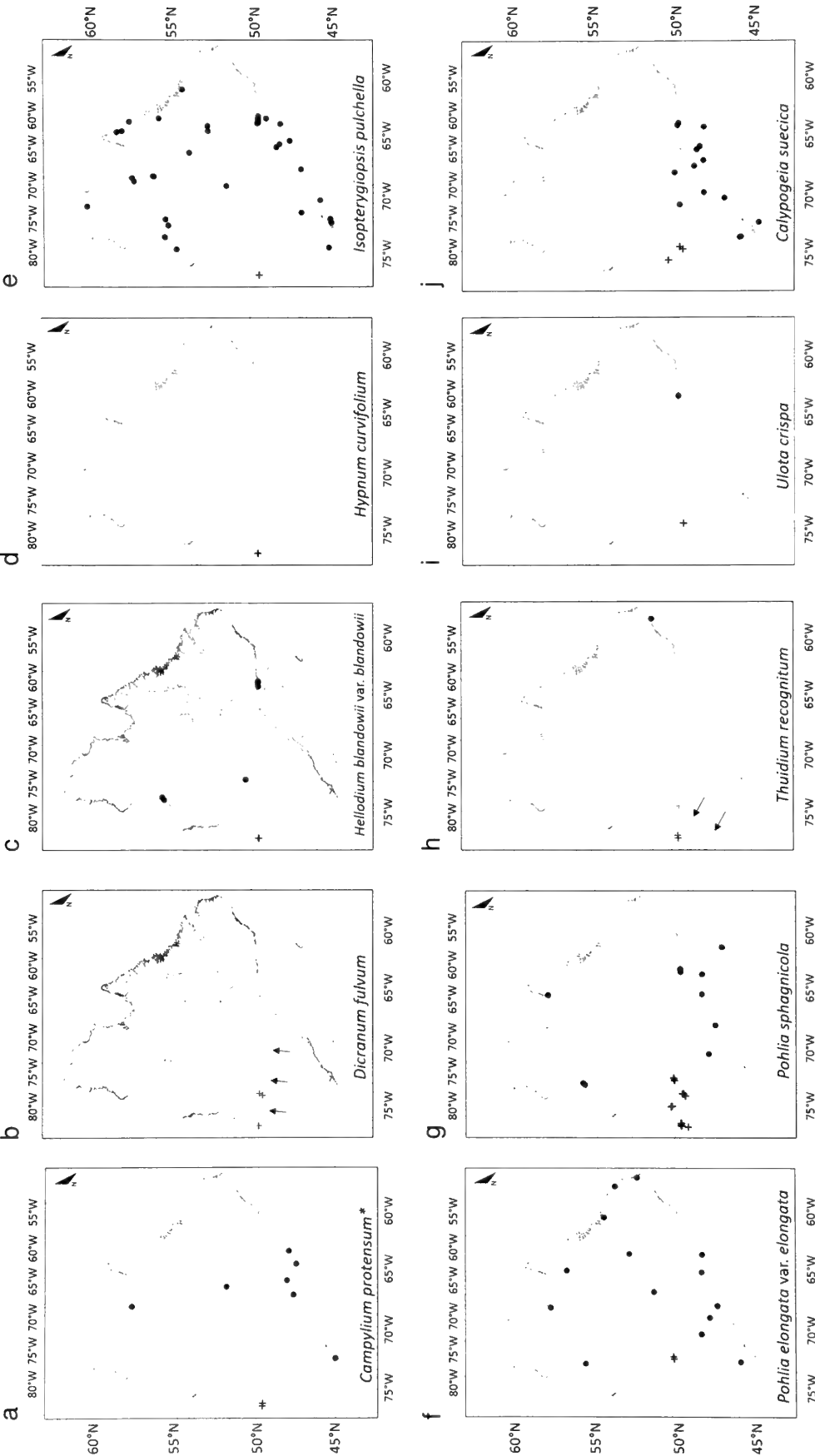
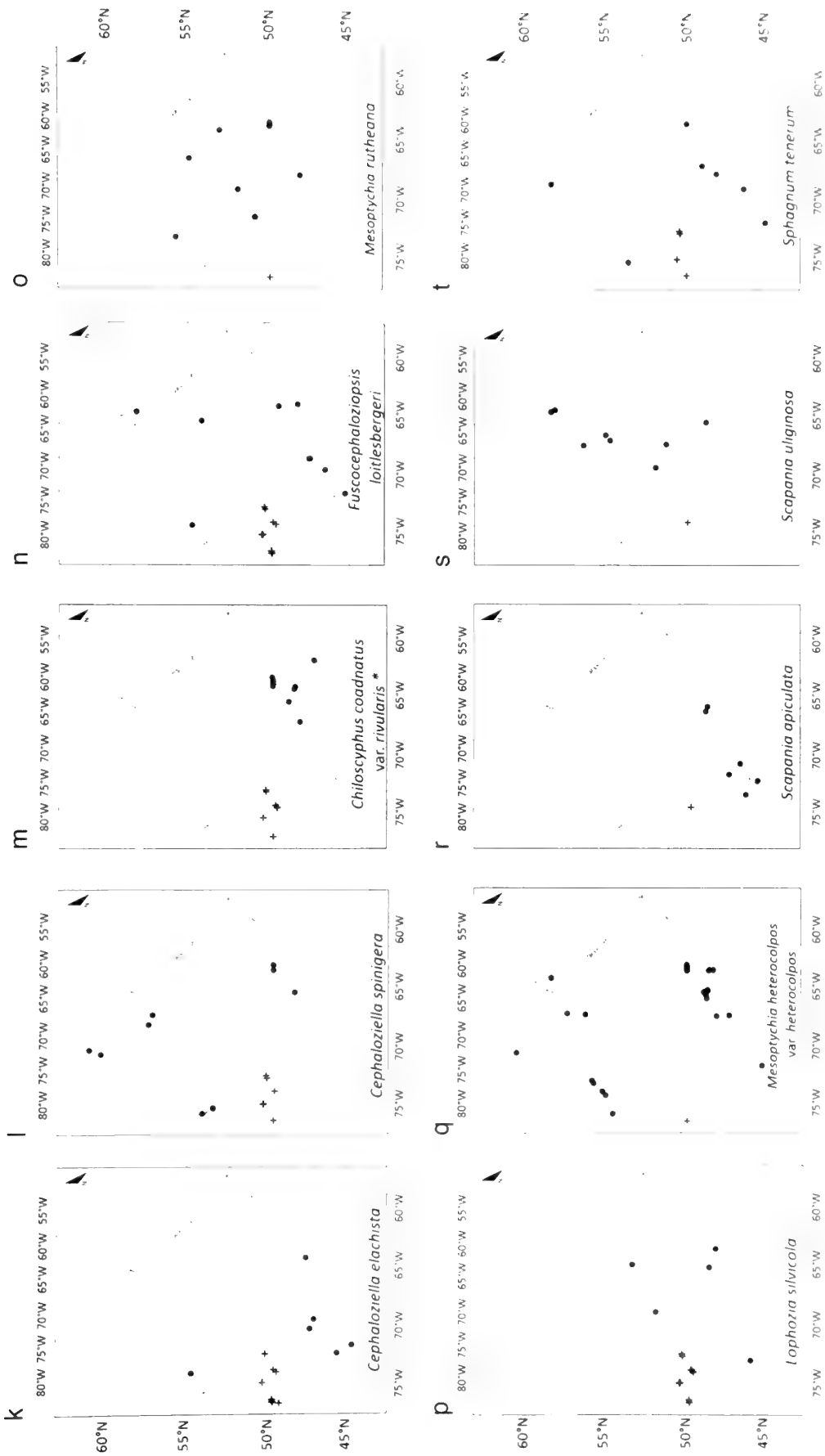


FIGURE 4A. Distributional ranges of species of group 3 (20 in total), comprising new occurrences in the study area with range extensions 77 km to > 650 km from their closest previously documented occurrence: a. *Campylopus protensus*, b. *Dicranum fulvum*, c. *Helodinium blandowii* var. *blandowii*, d. *Hypnum curvifolium*, e. *Isopterygiopsis pulchella*, f. *Pohlia elongata* var. *elongata*, g. *Pohlia sphagnicola*, h. *Thuidium recognitum*, i. *Uloata crispa*, j. *Calypogeia suecica*. Dots show previously documented occurrences; plus signs are new occurrences. The shaded zone represents areas where the species were already known in the province or the boreal Black Spruce feather moss forest in cases where the new occurrences suggest that the species may be found throughout the entire bioclimatic domain. A gradient in a shaded zone indicates that continuous species distribution in the area is uncertain, given the few occurrences reported in the lighter grey areas; arrows show the direction of range extension. Asterisks indicate species that are provincially rare according to Faubert *et al.* (2014+).



418. Distributional ranges of species of group 3 (20 in total), comprising new occurrences in the study area with range extensions 77 km to > 650 km from their closest previously documented occurrence: k. *Cephalozia elachista*, l. *Cephalozia spinigera*, m. *Chiloscypus coadnatus* var. *rivularis*, n. *Fuscocephaloziopsis loutleybergii*, o. *Mesoptychia rutheana*, p. *Lophozia silvicola*, q. *Mesoptychia heterocolpos* var. *heterocolpos*, r. *Scapania apiculata*, s. *Scapania uliginosa*, t. *Sphagnum tenerum*. See Figure 4A for meaning of symbols.

cause only one occurrence of each species was recorded in the study area, and the distance from the rest of their known Quebec range is substantial (325, 270, and 165 km, respectively).

Finally, the few occurrences (generally < 10) of the remaining 14 species do not suggest a continuous distribution of those species, but rather their sporadic presence over the study area. The new occurrences of *Brachythecium erythrorrhizon*, *Isopterygiopsis muel-leriana*, *Polytrichum commune* var. *perigoniale*, *Lophozia ascendens*, and *L. bicrenata* close gaps in their provincial distribution between southern and northern Quebec but also, in the case of *B. erythrorrhizon* and *P. commune* var. *perigoniale*, between eastern Quebec and Ontario. Furthermore, we document the presence of *Campylium protensum*, *Isopterygiopsis pulchella*, *Pohlia elongata* var. *elongata*, *Calypogeia suecica*, *Mesoptychia rutheana*, *M. heterocolpos* var. *heterocolpos*, *Scapania apiculata*, and *S. uliginosa* in the southern portion of Nord-du-Québec, 260–670 km west of their previously documented Quebec occurrences.

Our discoveries of the rare true mosses *Campylium protensum* and *Hypnum fauriei* and the rare liverworts *Chiloscyphus coadnatus* var. *rivularis*, *Odontoschisma francisci*, and *Schistochylopsis laxa*, confirm the importance of bryophyte sampling efforts in the neglected regions of Quebec–Labrador. However, some of the species described here may be misunderstood as a result of under-sampling or taxonomic confusion. Recent changes in species taxonomy have made herbarium specimens unreliable descriptors of species abundance until they can be re-examined and their identifications confirmed.

Finally, considering a larger geographic perspective, even though our findings represent significant distributional extensions within the province of Quebec, for some species the distance from the adjoining Ontario populations is less substantial (50–200 km, on average, from our study area). However, bryophyte distributions in Ontario are not as well or as recently documented as in Quebec (Faubert 2012–2014). Therefore, it is difficult to evaluate the exact distances between species occurrences. These species were found in eastern Ontario, in some localities of the Hudson Bay lowlands, and the Clay Belt region. The Clay Belt straddles Quebec and Ontario and its specific soil conditions may explain why the two provinces shared bryophyte assemblages.

Conclusions and Implications for Management and Conservation

This study suggests that numerous bryophytes may be more common than expected in Quebec–Labrador. We present a substantially revised and updated list of the bryoflora of the southern Nord-du-Québec administrative region. The updated ranges documented here can not only be used to redefine the protection priority ranks of these species, but may also aid in predicting the impacts of forest harvest and global climate changes. At the microhabitat level, our results indicate that some

species had singular preferences in terms of habitat in the Black Spruce forest compared with other ecosystems across the province. Species found in our study occupied, in general, more diverse microhabitats and particularly more woody ones.

The southern portion of the Nord-du-Québec administrative region is considered by Quebec bryologists to be a “black hole” in terms of knowledge about the distribution of the bryophyte flora, reflecting the paucity of sampling efforts in the region rather than species. Substantial work is still needed to map bryophyte distributions accurately in the province. Furthermore, increased sampling and the consultation of herbarium specimens will be required to fully understand the distribution and microhabitat preferences of bryophytes throughout North America. Efforts should be made in boreal feather moss forests, which may be defined as “bryo-diversity hotspots” in view of the occurrences of uncommon, infrequent, and rare bryophyte species and, therefore, require particular conservation attention.

Acknowledgements

Funding for this study was provided by fellowships from the Fonds de Recherche du Québec–Nature et Technologies, the Natural Sciences and Engineering Research Council of Canada, and the University du Québec en Abitibi-Témiscamingue. We thank Philippe Heine and Flora Joubier for their help in collecting bryophyte samples. We also sincerely thank the Editor-in-Chief Dwayne Lepitzki, the Associate Editor Jeff Saarela, and the reviewers of our paper, including Jennifer Doubt, for the constructive comments that led to this improved version of our paper.

Literature Cited

- Barbé, M., N. J. Fenton, and Y. Bergeron. 2016. So close and yet so far away: long-distance dispersal events govern bryophyte metacommunity reassembly. *Journal of Ecology* 104: 1707–1719. <https://doi.org/10.1111/1365-2745.12637>
- Barbé, M., N. J. Fenton, and Y. Bergeron. 2017. Are post-fire residual forest patches refugia for boreal bryophyte species? Implications for ecosystem based management and conservation. *Biodiversity and Conservation* 26: 943–965. <https://doi.org/10.1007/s10531-016-1281-9>
- Bergeron, Y., S. Gauthier, M. Flannigan, and V. Kafka. 2004. Fire regimes at the transition between mixedwood and coniferous boreal forest in northwestern Quebec. *Ecology* 85: 1916–1932. <https://doi.org/10.1890/02-0716>
- Bisbee, K. E., S. T. Gower, J. M. Norman, and E. V. Nordheim. 2001. Environmental controls on ground cover species composition and productivity in a boreal black spruce forest. *Oecologia* 129: 261–270. <https://doi.org/10.1007/s004420100719>
- Caners, R. T., S. E. Macdonald, and R. J. Belland. 2013. Linking the biological traits of boreal bryophytes to forest habitat change after partial harvesting. *Forest Ecology and Management* 303: 184–194. <https://doi.org/10.1016/j.foreco.2013.04.019>
- CNALH (Consortium of North American Lichen Herbaria). 2017. Accessed 30 June 2017. <http://bryophyteportal.org/portal/>

- Crawford, R. M. M., C. E. Jeffree, and W. G. Rees.** 2003. Paludification and forest retreat in northern oceanic environment. *Annals of Botany* 91: 213–226. <https://doi.org/10.1093/aob/mcf185>
- Crum, H. A., and L. E. Anderson.** 1981. *Mosses of Eastern North America*. Volumes 1 and 2. Columbia University Press, New York, New York, USA.
- Dynesius, M., and K. Hylander.** 2007. Resilience of bryophyte communities to clear-cutting of boreal stream-side forests. *Biological Conservation* 135: 423–434. <https://doi.org/10.1016/j.biocon.2006.10.010>
- Environment Canada.** 2017. Temperature and precipitation graph for 1981 to 2010 Canadian climate normals: Lebel-sur-Quévillon. Environment Canada, Ottawa, Ontario, Canada. Accessed 1 February 2016. <https://tinyurl.com/y87ccc7j>.
- Faubert, J.** 2007. Catalogue des bryophytes du Québec et du Labrador. *Provancheria* 30. Mémoire de l'Herbier Louis-Marie, Université Laval, Québec, Québec, Canada.
- Faubert, J.** 2012–2014. *Flora des Bryophytes du Québec Labrador*. Volumes 1, 2, and 3. Société québécoise de bryologie, Saint-Valérien, Québec, Canada.
- Faubert, J., D. F. Bastien, M. Lapointe, et C. Roy.** 2012. Cinq hépatiques nouvelles pour le Québec. *Carnets de bryologie* 2: 12–16.
- Faubert, J., et J. Gagnon.** 2013. Bryophytes nouvelles pour le Québec. *Carnets de bryologie* 3: 28–38.
- Faubert, J., S. Leclerc, A. Lavoie, M. Lapointe, S. Nadeau, M. Lamond, et collaborateurs.** 2014+. Base de données des bryophytes du Québec Labrador (BRYOQUEL). Société québécoise de bryologie, Saint-Valérien-de-Rimouski, Québec, Canada. Accessed 2 March 2016. <http://societequebecoisdebryologie.org>.
- Faubert, J., B. Tardif, et M. Lapointe.** 2010. Les bryophytes rares du Québec. Espèces prioritaires pour la conservation. Working paper. Centre de données sur le patrimoine naturel du Québec, Direction du patrimoine écologique et des parcs, Ministère du Développement durable, de l'Environnement et des Parcs, Gouvernement du Québec, Québec, Québec, Canada.
- Fenton, N. J., and K. A. Frego.** 2005. Bryophyte (moss and liverwort) conservation under remnant canopy in managed forests. *Biological Conservation* 122: 417–430. <https://doi.org/10.1016/j.biocon.2004.09.003>
- Fenton, N. J., N. Lecomte, S. Légaré, and Y. Bergeron.** 2005. Paludification in black spruce (*Picea mariana*) forests of eastern Canada: potential factors and management implications. *Forest Ecology and Management* 213: 151–159. <https://doi.org/10.1016/j.foreco.2005.03.017>
- Flora of North America Editorial Committee.** 2007. *Flora of North America, North of Mexico* (Volume 27). Bryophytes: Moss, Part 1. Oxford University Press, Oxford, United Kingdom.
- Gauthier, R.** 2011. Le genre *Tetradontium* (Tetraphidaceae, Musci) au Québec. *Carnet de bryologie* 1: 10–14.
- Grondin, P.** 1996. Écologie forestière. Pages 133–279 in *Manuel de foresterie*. Edited by J. A. Bérard and M. Côté. Presses de l'Université Laval, Québec, Québec, Canada.
- Hylander, K., M. Dynesius, B. G. Jonsson, and C. Nilsson.** 2005. Substrate form determines the fate of bryophytes in riparian buffer strips. *Ecological Applications* 15: 674–688. <https://doi.org/10.1890/04-0570>
- Ireland, R. R.** 1982. *Moss Flora of the Maritime Provinces*. National Museum of Natural Sciences of Canada, Ottawa, Ontario, Canada.
- Ireland, R. R., and L. M. Ley.** 1992. *Atlas of Ontario Mosses*. Canadian Museum of Nature, Ottawa, Ontario, Canada.
- Ley, L. M., and J. M. Crowe.** 1999. *An enthusiasts' guide to the liverworts and hornworts of Ontario*. Lakehead University, Thunder Bay, Ontario, Canada.
- Moisan, C., et S. Pellerin.** 2011. Présence de la céphalozie des marais (*Cephalozia macrostachya* Kaal., Cephaloziaceae, Marchantiophyta) au Québec. *Carnet de bryologie* 1: 23–25.
- Newmaster, S. G., R. J. Belland, A. Arsenault, D. H. Vitt, and T. R. Stephens.** 2005. The ones we left behind: comparing plot sampling and floristic habitat sampling for estimating bryophyte biodiversity. *Diversity and Distributions* 11: 57–72. <https://doi.org/10.1111/j.1366-9516.2005.00123.x>
- Payette, S., et A. Bouchard.** 2001. Le contexte physiographique et biogéographique. Pages 9–38 in *Écologie des tourbières du Québec-Labrador*. Edited by S. Payette and L. Rochefort. Les presses de l'Université Laval, Québec, Québec, Canada.
- Proctor, M. C. F.** 2011. Climatic responses and limits of bryophyte: comparisons and contrasts with vascular plants. Pages 35–54 in *Bryophyte Ecology and Climate Change*. Edited by Z. Tuba, N. G. Slack, and L. R. Stark. Cambridge University Press, New York, New York, USA.
- Saucier, J. P., P. Grondin, A. Robitaille, J. Gosselin, C. Morneau, P. J. H. Richard, J. Brisson, L. Sirois, A. Leduc, H. Morin, E. Thiffaut, S. Gauthier, C. Lavoie, et S. Payette.** 2009. Écologie forestière. Pages 165–316 in *Manuel de foresterie* (2nd edition). Edited by Ordre des ingénieurs forestiers du Québec. Éditions Multimondes, Boisbriand, Québec, Canada.
- Schuster, R. M.** 1966–1992. *The Hepaticae and Anthocerotae of North America* (Volume 1 to 6). Columbia University Press, New York, New York, USA.
- Simard, M., N. Lecomte, Y. Bergeron, P. Y. Bernier, and D. Paré.** 2007. Forest productivity decline caused by successional paludification of boreal soils. *Ecological Applications* 17: 1617–1637. <http://doi.org/10.1890/06-1795.1>
- SOPFEU (Société de protection des forêts contre le feu).** 2011. Digital map of the fires in Quebec from 1994 to 2003. fl094-3003-regecol.2 Geo83-P. SOPFEU, Val d'Or, Québec, Canada.
- Turetsky, M. R., B. Bond-Lamberty, E. Euskirchen, J. Talbot, S. Frolking, A. D. McGuire, and E.-S. Tuittila.** 2012. The resilience and functional role of moss in boreal and arctic ecosystems. *New Phytologist* 196: 49–67. <https://doi.org/10.1111/j.1469-8137.2012.04254.x>
- Vincent, J. S., et L. Hardy.** 1977. L'évolution et l'extinction des lacs glaciaires Barlow et Ojibway en territoire québécois. *Géographie physique et Quaternaire* 31: 357–372.

Received 16 January 2017
Accepted 5 September 2017

SUPPLEMENTARY MATERIAL:

APPENDIX S1. Number of plots where bryophyte taxa were found in residual forest patches and burned areas in boreal Black Spruce–feather moss forest in the southern portion of the Nord-du-Québec administrative region, western Quebec, Canada.

Observations of Beachcast Bowhead Whales (*Balaena mysticetus*) in the Southeastern Beaufort Sea and Amundsen Gulf, 1987–2016

LOIS A. HARWOOD^{1,6}, ELLEN V. LEA², STEPHEN A. RAVERTY³, PATRICIA A. HALL⁴, ERIN LINN⁵, LIANNE POSTMA⁴, and OLE NIELSEN⁴

¹Fisheries and Oceans Canada, 301 5204 50th Avenue, Yellowknife, Northwest Territories X1A 1E2 Canada

²Fisheries and Oceans Canada, P.O. Box 1871, Inuvik, Northwest Territories X0E 0T0 Canada

³Animal Health Center, British Columbia Ministry of Agriculture, 1767 Angus Campbell Road, Abbotsford, British Columbia V3G 2M3 Canada

⁴Fisheries and Oceans Canada, 501 University Crescent, Winnipeg, Manitoba R3T 2N6 Canada

⁵Golder Associates Ltd., 1721 8th Street East, Saskatoon, Saskatchewan S7H 0T4 Canada

⁶Corresponding author: lois.harwood@dfo-mpo.gc.ca

Harwood, Lois A., Ellen V. Lea, Stephen A. Raverty, Patricia A. Hall, Erin Linn, Lianne Postma, and Ole Nielsen. 2017. Observations of beachcast Bowhead Whales (*Balaena mysticetus*) in the southeastern Beaufort Sea and Amundsen Gulf, 1987–2016. *Canadian Field-Naturalist* 131(3): 270–279. <https://doi.org/10.22621/cfn.v131i3.2028>

Each spring, most Bowhead Whales (*Balaena mysticetus*) of the Bering-Chukchi-Beaufort (BCB) population migrate to the Canadian Beaufort Sea and Amundsen Gulf for summer feeding. Occasionally, Inuvialuit hunters and others observe beachcast (stranded) or adrift Bowhead Whale carcasses. From 1987 to 2016, 26 such occurrences were recorded. Most (65%) were found by Inuvialuit hunters travelling on the land, with the majority (54%) reported during 2000–2006. Bowhead Whale carcasses were found widely distributed throughout the region, with twice as many in Amundsen Gulf (65%) compared with the southeastern Beaufort Sea (35%). It was possible to measure or estimate standard length for 17 of 26 specimens, and all were either provisional ‘subadults’ (7–9.5 m; $n = 10$; 59%) or provisional ‘mature adults’ (13–16 m; $n = 7$; 41%). The cause(s) of mortality was not determined for any of the specimens. Whales in the ‘subadult’ group were likely 1–4 years old, while the ‘mature adult’ group were likely mostly mature animals (~25 y), including some potentially very old (>100 y). There was evidence or direct observation of Polar Bears (*Ursus maritimus*) and/or Grizzly Bears (*U. arctos*) scavenging at 60% of the carcasses for which presence or absence of bears or bear sign (scats and/or tracks) was reported. It is important to continue to record incidental observations of beachcast Bowhead Whales, as this may enable stranding rates to be evaluated.

Key Words: *Balaena mysticetus*; Bowhead Whale; beachcast; stranding; Beaufort Sea; Amundsen Gulf

Introduction

Each spring, most Bowhead Whales (*Balaena mysticetus*) of the Bering-Chukchi-Beaufort (BCB) population migrate to the Canadian portion of the Beaufort Sea and the Amundsen Gulf to feed during the summer (Richardson *et al.* 1987; Moore and Reeves 1993; Harwood *et al.* 2010, 2017). They aggregate and forage there during August and September, with most starting their return westward to the Bering Sea wintering areas by mid to late September (Citta *et al.* 2015; ADFG 2017; Harwood *et al.* 2017).

The BCB population is listed as Special Concern under Canada’s *Species at Risk Act* (SARA Registry 2017) and endangered under the US *Endangered Species Act* (NOAA 2016). Bowhead Whales have a slow growth rate, a low reproductive rate, a late age of sexual maturity (~25 y; Rosa *et al.* 2013), and are extremely long-lived (oldest on record is a 14.6 m male, 211 y; George *et al.* 1999; Lubetkin *et al.* 2012). Based on the spring 2011 census at Point Barrow, Alaska, the most recent estimate of population size for the BCB population was 16 820 whales (95% CI = 15 176–18 643; Givens *et al.* 2016), representing an increase over the last decade. Clarke *et al.* (2013, 2014) reported that calf sighting rates increased during this same period, and

George *et al.* (2015) detected increases in the body condition of whales from 1989–2011, statistically so in subadults. Although future trajectories for population size and body condition are not known (George *et al.* 2015), a suite of indicators are presently showing positive or stable trends (George *et al.* 2017).

In the western Canadian Arctic, local Inuvialuit hunters, fishers, pilots, researchers, and park staff have observed and reported beachcast or drifting Bowhead Whale carcasses during recent decades. The co-management framework which is now in place with the implementation of the Inuvialuit Final Agreement (IFA; INAC 1986) has fostered and enhanced reporting of unusual occurrences of wildlife in the Inuvialuit Settlement Region (ISR), including beachcast Bowhead Whale carcasses. Our objective was to summarize the location and timing of beachcast Bowhead Whale reports in the western Canadian Arctic, by reviewing available stranding records for 1987 to 2016. Where feasible, our secondary objective was to examine the relative size of beachcast specimens, and examine the records for possible reason(s) for the mortalities. We also note observations of Grizzly Bear (*Ursus arctos*) and Polar Bear (*U. maritimus*) scavenging at beachcast Bowhead Whale carcasses.

Methods

People travelling in coastal areas of the Inuvialuit Settlement Region (i.e., subsistence hunters and fishers, and scientific, enforcement, aviation, and park staff) have made opportunistic observations of beacheast or drifting Bowhead Whale carcasses and reported these to Fisheries and Oceans Canada (DFO). Coastal areas of the ISR used by Inuvialuit harvesters for hunting and travel are extensive and include most coastlines (Figure 1). We do not have empirical records of the number of trips or hours of search effort that were involved in the discovery of the carcasses.

DFO has maintained a database of these incidental observations, including the reported locations, date and source of first observation or report, state of the carcass, and associated notes and photographs. Where practical and when resources and personnel were available, site visits were done to obtain additional photographs and length measurements (standard length, tip of rostrum to notch in tail), and in a few cases, to collect tissue samples and measure blubber thickness. The geographic locations of the carcasses were recorded with global positioning systems (GPS), or reported according to local landmarks and official or local geographic names. Locations where beacheast whales were initially observed were mapped using ArcGIS (Figure 2).

Skin tissue samples were collected from seven carcasses to molecularly determine gender (Table 1). These were preserved either in a salt-saturated 20% dimethyl sulfoxide (DMSO) solution (Seutin *et al.* 1991), or frozen as soon as possible after collection. These tissues were transferred to fresh salt/DMSO solution in the lab and archived at -20°C to -80°C . Total cellular DNA extractions were performed using DNeasy blood and tissue kit spin columns (Qiagen Hilden, Germany). A polymerase chain reaction (PCR) based method was used for molecular determination of gender following methods described by Rosel (2003) and Shaw *et al.* (2003). For most of the tissues, these different methods were used in tandem to verify gender assignment.

Results

From 1987 to 2016, 23 beacheast and three drifting Bowhead Whale carcasses were found opportunistically in the western Canadian Arctic and reported to DFO (Figure 2; Table 1). Most were discovered by Inuvialuit harvesters travelling on the land (65%), with the rest reported by others (e.g., pilots, researchers, government staff). Nearly half (47%) of the observations recorded during the 30-year period were from 2000 to 2006 (Table 1). Half of the years (15 of 30) had no occurrences, and the other years had 1–4 observations of beacheast Bowhead Whales per year.

Carcasses were reported from widely distributed locations (Figure 2), in both the southeastern Beaufort Sea (35%) and Amundsen Gulf (65%). The carcasses were clustered in several recurring locations, including Franklin Bay ($n = 4$), Darnley Bay including Pearce

Point ($n = 4$), along the Yukon coast ($n = 5$), off the southwest coast of Banks Island ($n = 5$), and in Prince Albert Sound ($n = 3$).

Carcasses were generally inaccessible for complete necropsy, due to their remote location, positioning on shore (e.g., portion sunk, buried), prevailing weather conditions, and/or the presence of bears; only one carcass was necropsied by a veterinary pathologist (Figure 3). Carcasses ranged from bone piles (Figure 3) to relatively intact carcasses (Figure 4). It was however possible to estimate or measure standard length of 17 (65%) of the carcasses, measure dorsal blubber thickness (25–30 cm) in three, and determine gender for two using molecular methods (Table 1).

The estimated whale lengths were all in one of two distinct size groupings, referred to here as provisional 'subadults' (7.0–9.5 m; $n = 10$; 59%) and provisional 'mature adults' (13–16 m; $n = 7$; 41%; Table 1) based on suggestions by George *et al.* (2011). No 'mature adults' were found west of Cape Bathurst, and mainly 'subadults' were found east of Cape Bathurst (Figure 2; Table 1). cursory external examination of some carcasses and in some cases archived photos did not yield clues as to the cause of death in any of the specimens. None of the carcasses had any external or obvious indications of predation by Killer Whales (*Orcinus orca*; George *et al.* 2004), or human interactions, such as ship-strike related trauma, or harpoons, floats, or attached ropes that would suggest the whale was struck-and-lost during subsistence hunting.

Of the 15 reports with notes about the presence/absence of bears, nine carcasses had one or more bears, or evidence of scavenging (scats and/or tracks) by Polar Bears and/or Grizzly Bears (Table 1). One carcass on the Yukon coast (no. 2; Table 1) had both bear species feeding on the carcass at the same time. A female Polar Bear with three cubs and three male Polar Bears were simultaneously feeding on a carcass (no. 8; Table 1) in southeastern Franklin Bay. At a relatively 'fresh' carcass on the western shores of Franklin Bay in 2000 (no. 7; Table 1), there were ten Grizzly Bears observed feeding at the carcass, and another six fled when the helicopter arrived and were sighted within 2–3 km in the nearby hills. A large male Grizzly Bear was observed at the Bowhead Whale carcass in Franklin Bay in August 2015 (Figure 4).

Discussion

Since 1987, there have been 26 opportunistic reports of beacheast or drifting bowhead carcasses in the western Canadian Arctic, 65% of these reported by Inuvialuit harvesters. The carcasses were widely distributed along the mainland coast and the southwest shores of Banks and Victoria islands in the Inuvialuit Settlement Region, with twice as many found on the shores of Amundsen Gulf (65%; all mature adults) compared with the southeastern Beaufort Sea (35%, mainly subadults). Polar Bears and/or Grizzly Bears were observed

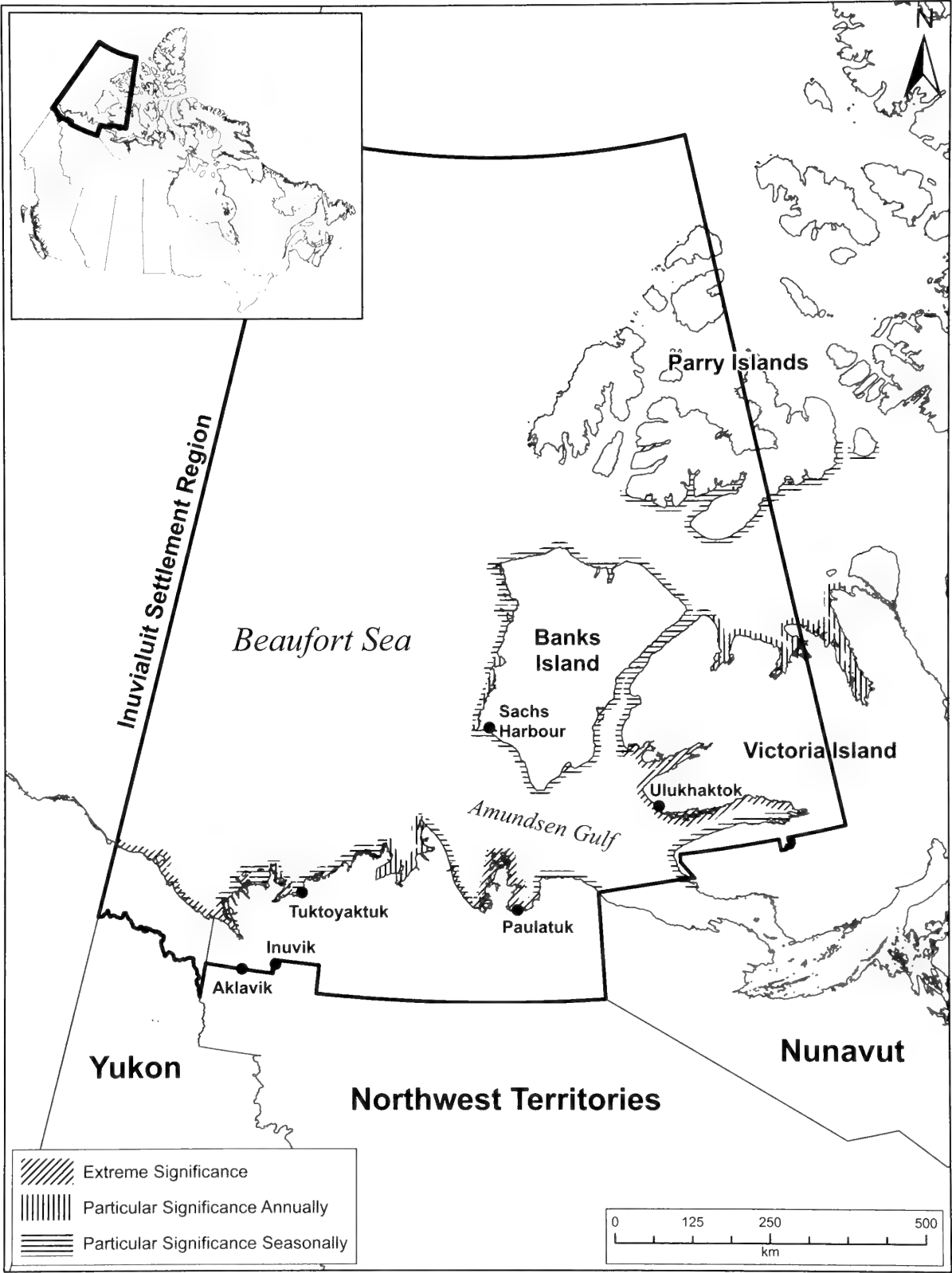


FIGURE 1. Coastlines in the Inuvialuit Settlement Region (ISR; polygon) self-identified by harvesters as having extreme or particular significance to ISR hunters. We infer these to include hunting and travelling routes that are regularly used (adapted from Community of Aklavik *et al.* 2008; Community of Inuvik *et al.* 2008; Community of Paulatuk *et al.* 2008; Community of Sachs Harbour *et al.* 2008; Community of Tuktoyaktuk *et al.* 2008; Community of Ulukhaktok *et al.* 2008).

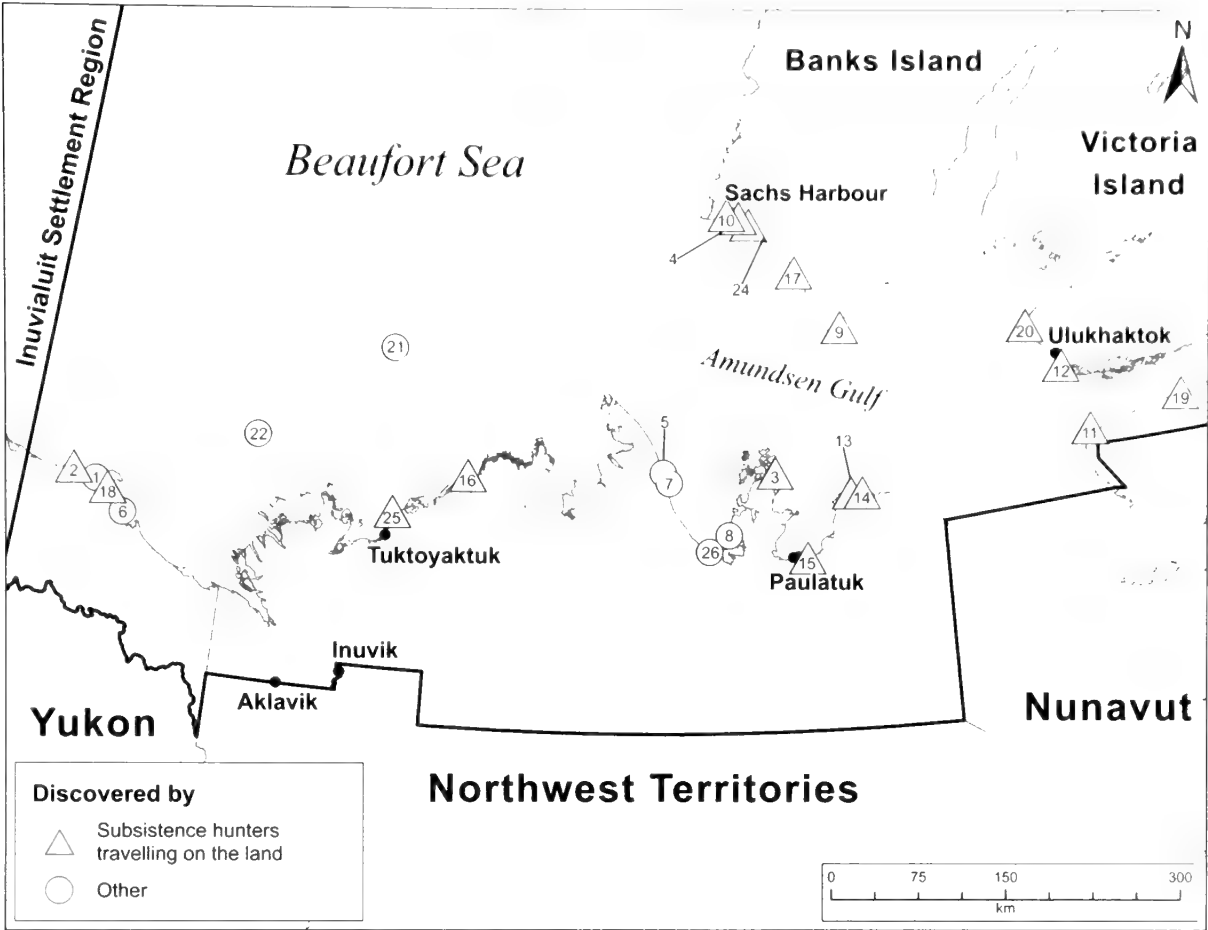


FIGURE 2. Location of beachcast and drifting Bowhead Whale (*Balaena mysticetus*) carcasses discovered in the western Canadian Arctic by hunters and others, 1987–2016 (whale number corresponds to Table 1).

at, or inferred to have been scavenging at, 60% of the carcasses. It was not possible to determine the cause(s) of mortality in any of the specimens.

Hunters from the ISR that found these carcasses have self-identified the lands and waters where cultural and renewable resources are of extreme significance and sensitivity (Figure 1), and we infer these to be the most intensely ‘searched’ coastlines during hunting and other traditional travel-based activities. Hunter reports of beachcast animals, ‘accidental’ wildlife sightings, predation accounts, and information on animal behaviour are some of the best examples of “local ecological knowledge” (Noongwook *et al.* 2007). Additionally, the onshore locations where the carcasses are discovered likely reflect, at least in part, a combination of prevailing winds, currents, and bathymetry that tends to concentrate the carcasses and wash them ashore (Figure 2). Similarly, flight routes used by light commercial aircraft are generally established and consistent, as are the locations where park staff work (airstrips and parks), although deviations from typical routes due to weather, altitude, or destination cannot be discounted.

Despite the limitations and biases associated with the data from beachcast whales, including an inability to quantify search effort, the database is unique in that it provides a long-term record of occurrences.

Our efforts to determine the cause of mortality and establish baseline health parameters were hindered by our inability to access fresh carcasses in a timely manner. None of the carcasses had any obvious evidence of predation or ship strike-related wounds, although most were in an advanced state of decomposition. Length measurements were subject to error due to decomposition, scavenging, access, and positioning of the carcass. Evidence of freeze and thaw cycles in successive winter seasons (Table 1) further confounds the comparison of inter-annual data. The blubber thickness measured on the three specimens was consistent with that for healthy landed bowheads (George 2009), although blubber thickness may not be the best indicator of nutritional state. A more recent study indicates adipocyte size and fibre density may be more informative indicators of body condition (Ball *et al.* 2015).

TABLE 1. Beachcast and adrift Bowhead Whale (*Balaena mysticetus*) carcasses observed in the southeast Beaufort Sea and Amundsen Gulf, from 1987 to 2016, as recorded by, or reported to, Fisheries and Oceans Canada (no data = -).

Whale #	Carcass first observed		On-site inspection of carcass by technical staff	Estimated length (m)*	Size class†	Discovered and/or reported to DFO by	Sex	Blubber thickness (cm)	No. bears ‡ observed or evidence of bears, scavenging (scats and/or tracks) at carcass
	Year	Month							
1	1987	9	yes	9§	subadult	DFO staff	-	-	-
2	1991	-	no	-	-	Aklavik Hunter	-	-	3 (GB) + 1 (PB)
3	1989	7	no	7	subadult	Paulatuk Hunter	-	-	-
4	1993	8	no	13-14	mature adult	Sachs Harbour HTC/hunters	-	-	-
5	1995	4	yes	16§	mature adult	pilot report	-	-	scavenged
6	1996	8	yes	9	subadult	parks crew	male	-	-
7	2000	9	yes	8.9	subadult	pilot report	-	25-30	-
8	2000	9	yes	14	mature adult	unknown	-	-	10 (GB) 7 (PB)¶
9	2003	4	no	-	-	Sachs Harbour hunters	-	-	-
10	2003	7	yes	14	mature adult	parks crew	female	30	no
11	2003	8	yes	14	mature adult	Uluksaktok hunters	-	-	scavenged
12	2003	9	no	-	-	Uluksaktok hunters	-	-	no
13	2004	8	no	14	mature adult	Paulatuk hunters	-	-	4 (GB)
14	2004	8	no	9.5§	subadult	Paulatuk hunters	-	-	-
15	2004	8	yes	14	mature adult	Paulatuk hunters	-	30	no
16¶	2004	12	yes	8	subadult	Paulatuk hunters	-	-	scavenged
17	2005	7	yes	8.2§	subadult	Tuktoyaktuk hunters/wildlife officers	-	-	-
18	2005	-	no	-	-	Sachs Harbour hunters	-	-	-
19	2006	8	no	-	-	Tuktoyaktuk hunters	-	-	-
20	2006	-	no	-§	-	Uluksaktok hunters	-	-	-
21	2009	10	no	8	subadult	Uluksaktok hunters	-	-	no
22	2009	10	no	-	-	Coast Guard ship	-	-	no
23	2010	8	no	9	subadult	Coast Guard ship	-	-	no
24	2014	8	no	-§	-	parks crew	-	-	-
25	2015	8	yes	9.2	subadult	Sachs Harbour hunters	-	-	scavenged
26	2015	9	no	-	-	Tuktoyaktuk hunters	-	-	no
						canoeists reported to Paulatuk HTC	-	-	1 (GB)

*Not possible or practical to estimate measurement error.

†Provisional subadult = 7-9.5 m; provisional mature adult = > 13 m.

‡GB = Grizzly Bear (*Ursus arctos*); PB = Polar Bear (*Ursus maritimus*).

§State of decomposition suggested whale was beachcast in previous year(s).

¶Female Polar Bear, three cubs, and three male Polar Bears feeding.

*Whale was accessible and necropsied by a veterinary pathologist on 15 July 2005 (Figure 3), > 8 months after stranding. The carcass was in an advanced stage of decomposition.

In cases where fresh carcasses are examined, such as is possible with Alaskan subsistence harvests, very few Bowhead Whales are found with any pathology (George *et al.* 1999), and blubber thickness and body condition of subadults have been showing a positive trend over the past 20 years (George *et al.* 2015). Bowheads have a long evolutionary history and are considered to possess protective molecular adaptations relevant to age-related diseases (Keane *et al.* 2015). Although the only

known natural cause of death in a stranded Bowhead Whale was attributed to intestinal volvulus (Heidel and Albert 1994), recent detection of harmful algal (HABs) toxins in harvested and stranded marine mammals in Alaska in 2014 suggest this could be a potential contributing factor to future whale morbidity and loss (Lefebvre *et al.* 2016). As well, detection of an exotic pathogen, phocine distemper virus in Alaskan Sea Otters (*Enhydra lutris*), suggests a possible route of intro-



FIGURE 3. Veterinary pathologist, assisted by technical staff from Fisheries and Oceans Canada and the community of Tuktoyaktuk, Northwest Territories, conducting a necropsy of a highly decomposed "subadult" beachcast Bowhead Whale (*Balaen mysticetus*) carcass, Atkinson Point, Northwest Territories, Canada (no. 16, Figure 2). Photo: T. Lynn.



FIGURE 4. Bowhead Whale (*Balaena mysticetus*) 'adult' carcass at Franklin Bay with Grizzly Bear (*Ursus arctos*) scavenging (no. 26, Figure 2). Photo: B. Orkin.

duction via the Northwest Passage (Goldstein *et al.* 2009). Exposure of Bowhead Whales to other novel pathogens may also be a consideration.

Another possible explanation for death would be natural mortality. Despite the above mentioned limitations in measuring carcasses, given the 4 m separation in length between our 'subadult' and 'adult' age classes, it is unlikely that we would have assigned specimens to the wrong group. George *et al.* (2015) suspect that Bowhead Whales are most vulnerable to environmental vagaries when standard length is 8–10 m, and this matches with our 'subadult' group. Mortalities in this category may reflect early life stage events that coincide with a time of weight loss and growth of baleen racks (George *et al.* 2016). Our provisional 'adult' group most likely consisted of sexually mature whales, some potentially very old, although recently or nearly matured whales may have also been included (Koski *et al.* 1988, 1993). Mortality in our 'adult' group likely includes senescent mortality, but to an unknown extent.

Stable and positive trends observed in this population in recent years (see George *et al.* 2017) may be linked with enhanced production of the bowhead's planktonic prey, associated with the changing climate (Moore

et al. 2014; Arrigo and van Dijken 2015; George *et al.* 2015; Moore and Stabeno 2015; Wood *et al.* 2015). It could also include an increase in whale abundance since the cessation of commercial whaling in the early 1900s (McGhee 1988); population size has shown a strong recovery and has now approached pre-contact estimates of population size (Woodby and Botkin 1993; Brandon and Wade 2006).

Finally, based on the absence of observed harpoons, floats or ropes, or other signs of prior strikes, there was no indication of beachcast Bowhead Whales having been struck-but-lost by harvesters, as reported in Alaska (NOAA 2017a). The only recent subsistence harvests of Bowhead Whales in the western Canadian Arctic were in 1991 (Freeman *et al.* 1992) and 1994 (Harwood and Smith 2002). Prior to the 1991 harvest, the last recorded landed bowhead in this region was in 1925 (McGhee 1988). The reasons for the concentration of reported mortalities in the mid-early 2000s are not known, but for the reasons above, we do not attribute these to be hunting losses by Canadian hunters.

The geographic separation of carcasses, with 'subadults' in the Beaufort Sea and 'adults' in Amundsen Gulf, matches the segregation of subadults and adults

that has been observed during photogrammetric, telemetry, and aerial survey studies conducted in these same areas (Cubbage and Calambokidis 1987; Koski *et al.* 1988; Koski and Miller 2009; Harwood *et al.* 2010, 2017). In all of these cases, subadults occurred mainly in waters over the continental shelf in the Beaufort Sea, while mature animals used more distant habitats and deeper waters, particularly Amundsen Gulf (Koski and Miller 2009; Harwood *et al.* 2017). This may explain the propensity for beachcast specimens in the two age groups to be separated geographically.

The prevalence of bears and bear sign at the beachcast carcasses was also notable. There is growing evidence that subsistence-harvested Bowhead Whale carcasses (bone piles left after subsistence hunts in Alaska) are becoming increasingly important in the diet of Polar Bears, particularly because more bears are spending more time close to shore (Miller *et al.* 2015; Rogers *et al.* 2015). Although the extent of scavenging at Bowhead Whale bone piles varied among years, there are indications that the contribution of Bowhead Whale to the diet of Polar Bears is increasing (Bentzen *et al.* 2007; Herreman and Peacock 2013; Rogers *et al.* 2015).

Emerging and dramatic environmental change in the Arctic marine ecosystem (e.g., Moore and Staben 2015), coupled with anticipated increases in shipping traffic in the Arctic (Halliday *et al.* 2017), prompted us to compile the historical stranding records for the Canadian portion of the BCB Bowhead range. In the Alaskan portion of their range, which includes the western Beaufort Sea, Chukchi Sea, and Bering Sea, beachcast Bowhead Whales are similarly recorded through the Alaska Marine Mammal Stranding Network (NOAA 2017a). Together, these datasets are the most practical means to document occurrences, and may inform managers when considering trends in spatial and temporal stranding records, and often is the only metric available to assess marine mammal mortality events (NOAA 2017b). We urge keeping the database as standard and current as possible.

Acknowledgements

We gratefully acknowledge the many people who reported and/or investigated the beachcast Bowhead Whales in the Inuvialuit Settlement Region. R. Baker, S. Cosens, L. Dahlke, L. Emaghok, R. Ettagiak, J. Illasiak Jr., N. Robinson, late C. Ruben, F. Pokiak, K. Snow, J. Felix Jr., M. Branigan, P. Cott, J. Alikamik, A. Joss, J. Kuptana, N. Perry, J. Lucas, A. Tardiff, E. Raddi, and T. Stein, participated in field sampling (our apologies to anyone we may have missed). Coordinators/field leaders were assisted in the field by numerous hunters and technicians from the communities of Ulukhaktok, Sachs Harbour, Paulatuk, Aklavik, Inuvik, and Tuktoyaktuk, Northwest Territories. Funding was provided by DFO and the Fisheries Joint Management Committee. We are particularly grateful to the Hunters and Trappers Committees from Sachs Harbour, Paulatuk, Tuktoyaktuk,

Aklavik, and Ulukhaktok for notifying DFO of these occurrences and assisting with sampling. We thank C. George for providing advice and references relating to these occurrences over many years and in the preparation of this paper and J. Richardson for helpful comments on an earlier version. Figures 1 and 2 were prepared by J. Friesen of DFO, the latter based on an earlier iteration by D. Leonard. Preparation of this article was funded by DFO's Species at Risk Program. C. George, D. Lee, and T. Jung provided comments that improved this manuscript.

Literature Cited

- ADFG (Alaska Department Fish and Game). 2017. Bowhead Whale research, satellite tracking of western Arctic Bowhead Whales. Accessed 28 December 2017. <http://www.adfg.alaska.gov/index.cfm?adfg=marinemammalprogram.bowhead>.
- Arrigo, K. R., and G. L. van Dijken. 2015. Continued increases in Arctic Ocean primary productivity. *Progress in Oceanography* 136: 60–70. <https://doi.org/10.1016/j.pocean.2015.05.002>
- Ball, H. C., M. Stavarz, J. Oldaker, S. Usip, R. L. Londraville, J. C. George, J. G. Thewissen, and R. J. Duff. 2015. Seasonal and ontogenetic variation in subcutaneous adipose of the bowhead whale (*Balaena mysticetus*). *Anatomical Record* (Hoboken) 298: 1416–1423. <https://doi.org/10.1002/ar.23125>
- Bentzen, T. W., F. H. Follmann, S. C. Amstrup, G. S. York, M. J. Wooller, and T. M. O'Hara. 2007. Variation in winter diet of southern Beaufort Sea polar bears inferred from stable isotope analysis. *Canadian Journal of Zoology* 85: 596–608. <https://doi.org/10.1139/Z07-036>
- Brandon, J., and P. R. Wade. 2006. Assessment of the Bering-Chukchi-Beaufort Seas stock of bowhead whales using Bayesian model averaging. *Journal of Cetacean Research and Management* 8: 225–239.
- Citta, J. J., L. T. Quakenbush, S. R. Okkonen, M. L. Druckenmiller, W. Maslowski, J. Clement-Kinney, J. C. George, H. Brower, R. J. Small, C. J. Ashjian, L. A. Harwood, and M. P. Heide-Jorgensen. 2015. Ecological characteristics of core areas used by western Arctic bowhead whales, 2006–2012. *Progress in Oceanography* 136: 201–222. <https://doi.org/10.1016/j.pocean.2014.08.012>
- Clarke, J. T., A. A. Brower, C. L. Christman, and M. Ferguson. 2014. Distribution and relative abundance of marine mammals in the northeastern Chukchi and Western Beaufort seas. 2013. Annual Report, OCS Study BOEM 2014-018. National Marine Mammal Laboratory, Alaska Fisheries Science Center, Seattle, Washington, USA.
- Clarke, J. T., C. Christman, A. A. Brower, and M. Ferguson. 2013. Distribution and relative abundance of marine mammals in the northeastern Chukchi and Western Beaufort seas. 2012. Annual Report, OCS Study BOEM 2013-00117. National Marine Mammal Laboratory, Alaska Fisheries Science Center, Seattle, Washington, USA.
- Community of Aklavik, the Wildlife Management Advisory Council (NWT), and the Joint Secretariat. 2008. Aklavik Inuvialuit Community Conservation Plan. Accessed 28 December 2017. http://www.screeningcommittee.ca/pdf/cep/Aklavik_CCP.pdf.
- Community of Inuvik, the Wildlife Management Advisory Council (NWT), and the Joint Secretariat. 2008. Inuvik

- Inuvialuit Community Conservation Plan. Accessed 28 December 2017. http://www.screeningcommittee.ca/pdf/ccp/Inuvik_CCP.pdf.
- Community of Paulatuk, the Wildlife Management Advisory Council (NWT), and the Joint Secretariat.** 2008. Paulatuk Community Conservation Plan. Accessed 28 December 2017. http://www.screeningcommittee.ca/pdf/ccp/Paulatuk_CCP.pdf.
- Community of Sachs Harbour, the Wildlife Management Advisory Council (NWT), and the Joint Secretariat.** 2008. Sachs Harbour Community Conservation Plan. Accessed 28 December 2017. http://www.screeningcommittee.ca/pdf/ccp/SachsHarbour_CCP.pdf.
- Community of Tuktoyaktuk, the Wildlife Management Advisory Council (NWT), and the Joint Secretariat.** 2008. Tuktoyaktuk Community Conservation Plan. Accessed 28 December 2017. http://www.screeningcommittee.ca/pdf/ccp/Tuktoyaktuk_CCP.pdf.
- Community of Ulukhaktok, the Wildlife Management Advisory Council (NWT), and the Joint Secretariat.** 2008. Olokhtomiut Community Conservation Plan. Accessed 28 December 2017. http://www.screeningcommittee.ca/pdf/ccp/Ulukhaktok_CCP.pdf.
- Cubbage, J. C., and J. Calambokidis.** 1987. Size class segregation of bowhead whales discerned through stereo photogrammetry. *Marine Mammal Science* 3: 179–185. <https://doi.org/10.1111/j.1748-7692.1987.tb00160.x>
- Freeman, M. R., E. A. Wein, and D. E. Keith.** 1992. Recovering Rights, Bowhead Whales and Inuvialuit Subsistence in the Western Canadian Arctic. Occasional Publications Series, Studies on Whaling No. 2, University of Alberta Press, Edmonton, Alberta, Canada.
- George, J. C.** 2009. Growth, morphology, and energetics of bowhead whales (*Balaena mysticetus*). Ph.D. thesis, University of Alaska, Fairbanks, Alaska, USA.
- George, J. C., J. Bada, J. Zeh, L. Scott, S. E. Brown, T. O'Hara, and R. Suydam.** 1999. Age and growth estimates of bowhead whales (*Balaena mysticetus*) via aspartic acid racemization. *Canadian Journal of Zoology* 77: 571–580. <https://doi.org/10.1139/z99-015>
- George, J. C., M. L. Druckenmiller, K. L. Laidre, K. L., R. Suydam, and B. Person.** 2015. Bowhead whale body condition and links to summer sea ice and upwelling in the Beaufort Sea. *Progress in Oceanography* 136: 250–262. <https://doi.org/10.1016/j.pocan.2015.05.001>
- George, J. C., E. Follmann, J. Zeh, M. Sousa, R. Tarpley, R. Suydam, and L. Horstmann-Dehn.** 2011. A new way to estimate the age of bowhead whales (*Balaena mysticetus*) using ovarian corpora counts. *Canadian Journal of Zoology* 89: 840–852. <https://doi.org/10.1139/z11-057>
- George, J. C., L. M. Philo, K. Hazard, D. Withrow, G. M. Carroll, and R. Suydam.** 2004. Frequency of killer whale (*Orcinus orca*) attacks and ship collisions based on scarring on bowhead whales (*Balaena mysticetus*) of the Bering-Chukchi-Beaufort Seas Stock. *Arctic* 47: 247–255.
- George, J. C., R. Stimmelmayer, A. Brower, J. Clarke, M. Ferguson, A. Von Duyke, G. Sheffield, K. Stafford, T. Stormo, B. Person, L. Sousa, B. Tudor, and R. Suydam.** 2017. 2016 Health Report for the Bering-Chukchi-Beaufort Seas Bowhead Whales – Preliminary Findings prepared for International Whaling Commission SC/67/AWMP/10. Department of Wildlife Management, Barrow, Alaska. <https://doi.org/10.13140/RG.2.2.32608.07686>
- George, J. C., R. Stimmelmayer, R. Suydam, S. Usip, G. Givens, T. Sformo, and J. G. M. Thewissen.** 2016. Severe bone loss as part of the life history strategy of Bowhead Whales. *PLoS ONE* 11(6). <https://doi.org/10.1371/journal.pone.0156753>
- Givens, G. H., S. L. Edmondson, J. C. George, R. Suydam, R. A. Charif, A. Rahaman, D. Hawthorne, B. Tudor, R. A. DeLong, and C. W. Clark.** 2016. Horvitz-Thompson whale abundance estimate adjusting for uncertain recapture, temporal availability variation and intermittent effort. *Environmetrics* 26: 1–16. <https://doi.org/10.1002/env.2379>
- Goldstein, T., J. A. K. Mazet, V. A. Gill, A. M. Doroff, K. A. Burek, and A. Hammond.** 2009. Phocine distemper virus in Northern Sea Otters in the Pacific Ocean, Alaska, USA. *Emerging Infectious Diseases* 15: 925–927. <https://doi.org/10.3201/eid1506.090056>
- Halliday, W. D., S. J. Insley, R. C. Hilliard, T. de Jong, and M. K. Pine.** 2017. Potential impacts of shipping noise on marine mammals in the western Canadian Arctic. *Marine Pollution Bulletin* 123: 73–82. <https://doi.org/10.1016/j.marpolbul.2017.09.027>
- Harwood, L. A., and T. G. Smith.** 2002. Whales of the Inuvialuit Settlement Region in Canada's Western Arctic: an overview and outlook. *Arctic* 55 (Supplement 1): 77–93.
- Harwood, L. A., J. C. Auld, A. A. Joynt, and S. E. Moore.** 2010. Distribution of Bowhead Whales in the SE Beaufort Sea during late summer, 2007–2009. DFO Canadian Science Advisory Research Document 2009/111. Accessed 13 October 2017. <http://www.dfo-mpo.gc.ca/Library/340269.pdf>.
- Harwood, L. A., L. T. Quakenbush, R. J. Small, J. C. George, J. Pokiak, C. Pokiak, M. P. Heide-Jørgensen, E. V. Lea, and H. Brower.** 2017. Movements, habitat use, and inferred foraging by bowhead whales in the Canadian Beaufort Sea during August–September, 2006–2012. *Arctic* 70: 161–176. <https://doi.org/10.14430/arctic4648>
- Heidel, J. R., and T. F. Albert.** 1994. Intestinal volvulus in a bowhead whale, *Balaena mysticetus*. *Journal of Wildlife Diseases* 30: 126–128. <https://doi.org/10.7589/0090-3558-30.1.126>
- Herreman, J., and E. Peacock.** 2013. Polar bear use of a persistent food subsidy: insights from non-invasive genetic sampling in Alaska. *Ursus* 24: 148–163. <https://doi.org/10.2192/URSUS-D-12-00030.1>
- INAC (Indian and Northern Affairs Canada).** 1986. The Western Arctic Claim, Inuvialuit Final Agreement, As Amended. Accessed 6 June 2016. http://www.inuvialuitland.com/resources/Inuvialuit_Final_Agreement.pdf.
- Keane, M., J. Semeiks, A. Webb, Y. Li, V. Quesada, T. Craig, L. Madsen, S. van Dam, D. Brawand, P. I. Marques, P. Michalak, L. Kang, J. Bhak, H.-S. Yim, N. V. Grishin, N. H. Nielsen, M. P. Heide-Jørgensen, E. M. Oziolor, C. W. Matson, G. M. Church, G. W. Stuart, J. C. Patton, J. C. George, R. Suydam, K. Larsen, C. López-Otin, M. J. O'Connell, J. W. Bickham, B. Thomsen, and J. Pedro de Magalhães.** 2015. Insights into the evolution of longevity from the bowhead whale genome. *Cell Reports* 10: 112–122. <https://doi.org/10.1016/j.celrep.2014.12.008>
- Koski, W. R., R. A. Davis, G. W. Miller, and D. E. Withrow.** 1993. Reproduction. Pages 239–274 in *The Bowhead Whale*. Edited by J. J. Burns, J. J. Montague, and C. J. Cowles. Special Publication No. 2. The Society for Marine Mammalogy, Lawrence, Kansas, USA.
- Koski, W. R., and G. W. Miller.** 2009. Habitat use by different size classes of bowhead whales in the central Beaufort Sea

- during late summer and autumn. *Arctic* 62: 137–150. <https://doi.org/10.14430/arctic127>
- Koski, W. R., G. W. Miller, and R. A. Davis.** 1988. The potential effects of tanker traffic on the bowhead whale in the Beaufort Sea. *Environmental Studies* 58. Report NTIS MIC-90-04552 from LGL Limited, for the Department of Indian Affairs and Northern Development, Hull, Quebec, Canada.
- Lefebvre, K. A., L. Quakenbush, E. Frame, K. Burek Huntingdon, G. Sheffield, R. Stimmelmayer, A. Bryan, P. Kendrick, H. Ziel, T. Goldstein, J. A. Snyder, T. Gelatt, F. Gulland, B. Dickerson, and V. Gill.** 2016. Prevalence of algal toxins in Alaskan marine mammals foraging in a changing arctic and subarctic environment. *Harmful Algae* 55: 13–24. <https://doi.org/10.1016/j.hal.2016.01.007>
- Lubetkin, S. C., J. E. Zeh, and J. C. George.** 2012. Statistical modeling of baleen and body length at age in bowhead whales (*Balaena mysticetus*). *Canadian Journal of Zoology* 90: 915–931. <https://doi.org/10.1139/z2012-057>
- McGhee, R.** 1988. Beluga hunters: an archaeological reconstruction of the history and culture of the Mackenzie Delta Kittigaryumuit. Newfoundland Social and Economic Series No. 13. St. John's: Institute of Social and Economic Research, Memorial University of Newfoundland, St. John's, Newfoundland and Labrador, Canada.
- Miller, S., J. Wilder, and R. R. Wilson.** 2015. Polar bear-grizzly bear interactions during the autumn open-water period in Alaska. *Journal of Mammalogy* 96: 1317–1325. <https://doi.org/10.1093/jmammal/gyv140>
- Moore, S. E., E. Logerwell, L. Eisner, E. Farley, L. Harwood, K. Kuletz, J. Lovvorn, J. Murphy, and L. Quakenbush.** 2014. Marine fishes, birds and mammals as sentinels of ecosystem variability and reorganization in the Pacific Arctic region. Pages 337–392 in *The Pacific Arctic Sector: Status and Trends*. Edited by J. M. Grebmeier and W. Maslowski. First edition. Springer, Dordrecht, Holland.
- Moore, S. E., and R. R. Reeves.** 1993. Distribution and movement. Pages 313–386 in *The Bowhead Whale*. Edited by J. J. Burns, J. J. Montague, and C. J. Cowles. Special Publication No. 2. The Society for Marine Mammalogy, Lawrence, Kansas, USA.
- Moore, S. E., and P. J. Stabenro.** 2015. Synthesis of arctic research (SOAR) in marine ecosystems of the Pacific Arctic. *Progress in Oceanography* 136: 1–11. <https://doi.org/10.1016/j.pocean.2015.05.017>
- NOAA (National Oceanic and Atmospheric Administration).** 2016. NOAA Fisheries. Endangered Species Act. Accessed 6 June 2016. <http://www.nmfs.noaa.gov/pr/species/esa>.
- NOAA (National Oceanic and Atmospheric Administration).** 2017a. Marine Mammal Stranding Network, annual reports. Accessed 13 October 2017. <https://alaskafisheries.noaa.gov/pr/strandings>.
- NOAA (National Oceanic and Atmospheric Administration).** 2017b. Marine Mammal Unusual Mortality Events. Accessed 13 October 2017. http://www.nmfs.noaa.gov/pr/health/marine_events.html
- Noongwook, G., The Native Village of Savoonga, The Native Village of Gambell, H. P. Huntington, and J. C. George.** 2007. Traditional knowledge of the bowhead whale (*Balaena mysticetus*) around St. Lawrence Island, Alaska. *Arctic* 60: 47–54.
- Richardson, W. J., R. A. Davis, C. R. Evans, D. K. Ejungblad, and P. Norton.** 1987. Summer distribution of bowhead whales, *Balaena mysticetus*, relative to oil industry activities in the Canadian Beaufort Sea, 1980–1984. *Arctic* 40: 93–104. <https://doi.org/10.14430/arctic1753>
- Rogers, M. C., E. Peacock, K. Simac, M. B. O'Dell, and J. M. Welker.** 2015. Diet of female polar bears in the southern Beaufort Sea of Alaska: evidence for an emerging alternative foraging strategy in response to environmental change. *Polar Biology* 38: 1035–1047. <https://doi.org/10.1007/s00300-015-1665-4>
- Rosa, C., J. Zeh, J. C. George, O. Botta, M. Zauscher, J. Bada, and T. M. O'Hara.** 2013. Age estimates based on aspartic acid racemization for bowhead whales (*Balaena mysticetus*) harvested in 1998–2000 and the relationship between racemization rate and body temperature. *Marine Mammal Science* 29: 424–445. <https://doi.org/10.1111/j.1748-7692.2012.00593.x>
- Rosel, P. E.** 2003. PCR-based sex determination in Odontocete cetaceans. *Conservation Genetics* 4: 647–649. <https://doi.org/10.1023/A:1025666212967>
- SARA (Species at Risk) Registry.** 2017. Species profile. Bowhead Whale Bering-Chukchi-Beaufort population. Accessed 14 April 2017. http://www.registrelep-sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=131.
- Seutin, G., B. N. White, and P. T. Boag.** 1991. Preservation of avian blood and tissue samples for DNA analyses. *Canadian Journal of Zoology* 69: 82–90. <https://doi.org/10.1139/z91-013>
- Shaw, C. N., P. J. Wilson, and B. N. White.** 2003. A reliable molecular method of gender determination for mammals. *Journal of Mammalogy* 84: 123–128. [https://doi.org/10.1644/1545-1542\(2003\)084%3C0123:ARMMOG%3E2.0.CO;2](https://doi.org/10.1644/1545-1542(2003)084%3C0123:ARMMOG%3E2.0.CO;2)
- Wood, K. R., N. A. Bond, S. L. Danielson, J. E. Overland, S. A. Salo, P. J. Stabenro, and J. Whitefield.** 2015. A decade of environmental change in the Pacific Arctic region. *Progress in Oceanography* 136: 12–31. <https://doi.org/10.1016/j.pocean.2015.05.005>
- Woodby, D. A., and D. B. Botkin.** 1993. Stock sizes prior to commercial whaling. Pages 387–408 in *The Bowhead Whale*. Edited by J. J. Burns, J. J. Montague, and C. J. Cowles. Special Publication No. 2. The Society for Marine Mammalogy, Lawrence, Kansas, USA.

Received 13 June 2016

Accepted 10 October 2017

News and Comment

Great Canadian Field-Naturalists

As part of Canada's 150th birthday celebration, the Ottawa Field-Naturalists' Club (OFNC) is initiating the formal recognition of Canada's greatest field naturalists: individuals who made significant contributions to our knowledge of the natural history of Canada. This recognition will include:

- i) Developing a Great Canadian Field-Naturalist "Hall of Fame" on the OFNC website, and posting tributes with a description of each naturalist and a summary of his/her accomplishments;
- ii) Publishing the tribute in a special section in *The Canadian Field-Naturalist* (CFN);
- iii) Partnering with the Canadian Wildlife Federation and potentially other national conservation organizations, for dissemination through their websites, social media, and/or magazines.

Selection Process:

The selection will be made by a sub-committee of the OFNC Publications Committee. The sub-committee will solicit and accept nominations. The call for nominations will be disseminated broadly, including through publication in CFN, posting on the OFNC website, and through the various channels of communication with partners. Nominations should consist of a few paragraphs outlining the candidate's accomplishments against the selection criteria and be sent to editor@canadianfieldnaturalist.ca. Previously published Great Canadian Field-Naturalists tributes also should be reviewed for guidance. Nominations will be assessed as they are received. When a

nominee is selected, a Great Canadian Field-Naturalist tribute will be prepared, ideally by the person making the nomination. Nomination and selection will be ongoing.

Criteria for Selection:

Potential Candidates:

- Deceased individuals who were Canadian citizens or long-time, including seasonally recurring, residents of Canada;
- Recognition acknowledges lifetime achievement or many years of contribution within the scientific community;
- Contributions can be in either a professional or amateur capacity.

Character of Contributions:

- Significant contributions to our knowledge of the natural history of Canada;
- Contributions predominantly through field biology investigations and analyses within a single (e.g., botany, entomology, or zoology) or multi-disciplinary (e.g., botany and entomology) field and, not predominantly geological, cultural/educational, conservation, or resource management in orientation;
- Activities/contributions predominantly made in Canada and at regional to national geographic scales, rather than a localized scale;
- Contributions were documented in credible literature and/or with fully curated, publicly accessible specimen collections.

OFNC PUBLICATIONS COMMITTEE

Great Canadian Field-Naturalists: JAMES FLETCHER (28 March 1852–8 November 1908)

James Fletcher (Figure 1) was born in the hamlet of Ashe in southeastern England and privately developed considerable expertise in entomology (Lepidoptera) in this rural landscape. He received no specialized science training but graduated from Kings's School, Rochester with a well-rounded liberal education and with a particular proficiency in mathematics. He was initially employed at age 19 as an accounting clerk in England, immigrating to Canada (Montreal) in 1874, and then to Ottawa where he joined the staff of the Parliamentary Library as an accounting clerk in 1876. Under the mentorship of Parliamentary Librarian Alpheus Todd, he was also encouraged to conduct entomological research there. Fletcher was appointed Honourary Dominion Entomologist in 1884 and formally appointed as Dominion Entomologist and Botanist in 1886. He held that position until his untimely death in 1908. He is buried in Beechwood Cemetery in Ottawa, Ontario.

Major Area(s) of Natural History Contribution

Entomology (Lepidoptera, economic entomology, taxonomy); botany (vascular plants); public education; organizational and institutional development; biodiversity documentation.

Historical Summary

James Fletcher is credited with establishing the science of economic entomology as well as establishing the basis for plant pathology investigations in Canada. He is also notable for his establishment, in the absence of significant research resources, of a massive informational network of people engaged in agricultural activities throughout Canada. He maintained



FIGURE 1. James Fletcher with insect collecting net, Ottawa 1907. Photographer unknown; from Fletcher memorial issue, *The Ottawa Naturalist* 24(5) 1910.

correspondence with over 400 entomologists alone! Fletcher's contacts and associates included several internationally acclaimed intellectuals, including Alexander Graham Bell and evolutionist Alfred Russel Wallace.

At the same time, he was deeply involved with and promoted the study of Canadian native biodiversity for its own sake. He collected extensively across the country, ultimately donating these specimens (Figure 2) to form the foundation both for Canada's largest herbarium, the National Collection of Vascular Plants (DAO), and the largest insect collection in Canada, the Canadian National Collection of Insects (CNCI). Fletcher published extensively on native biodiversity, focusing on the natural history and taxonomy of insects and the control of agriculturally problematic species. He engaged as well in investigations on a wide variety of subjects, such as bird migration, geology, and environmental education. He



FIGURE 2. Voucher specimen of regionally rare Aquatic Beggars-ticks (*Bidens beckii*) collected by James Fletcher, W. H. Harrington, and H. Groh in Dows Lake, Ottawa, 7 September 1908 (DAO), likely the last plant specimen he collected. Image courtesy of Gisèle Mitrow, Agriculture and Agri Research Canada.

Great Canadian Field-Naturalists: JOHN MACOUN (17 April 1831- 18 July 1920)

John Macoun (Figure 1) was born in Northern Ireland to a farming family and immigrated with his parents and brother to Canada in 1850, to settle on a farm north of Belleville, Ontario. He had little formal education and certainly no academic training in natural sciences. Nonetheless, after brief study in 1859 at the Toronto Normal School (a teacher's college), he was accredited as an elementary school teacher and taught in several eastern Ontario communities over the following decade. During this period his botanical activities expanded from

was much in demand as a speaker and writer across Canada on such topics both in-person and through printed media.

Fletcher established innumerable first records through his personal field efforts and described a number of new insect species from that field work. A new species of dragonfly was named in honour of this work (Figure 3).

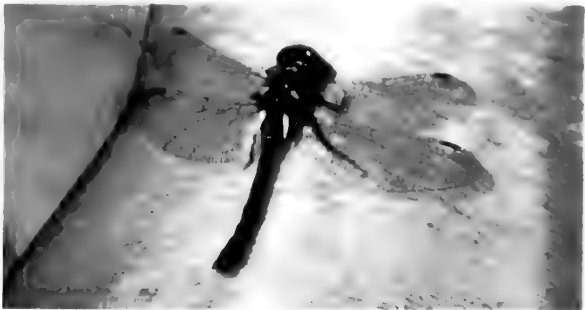


FIGURE 3. Fletcher's Dragonfly (*Williamsonia fletcheri*) perched on a field naturalist's hand, Alfred Bog, Ontario, 3 September 1984. Photo: Donald Cuddy.

His inspiration of individual field naturalists and his pivotal role in the establishment and development of regional, national, and international organizations such as the Ottawa Field-Naturalists' Club, The Entomological Society of Ontario, the Association of Economic Entomologists, and the Ottawa Horticultural Society, were equally significant contributions. Many of those organizations continue to contribute as he intended. In 1880 he served as the founding editor of the predecessor of *The Canadian Field-Naturalist*. He was also successful in enhancing the importance of investigations of Canadian natural sciences through his prominent positions and roles within influential national organizations such as the Royal Society of Canada.

All said and done, James Fletcher was likely the premier contributor amongst the group of largely self-taught resident 19th Century naturalists who pioneered the scientific investigation of Canadian biodiversity.

References

Anonymous. 1909. [Fletcher Memorial Issue] *The Ottawa Naturalist* 22(10).
Ansty, T. H. 1986. One Hundred Harvests. Research Branch, Agriculture Canada, Ottawa.
Brunton, D. F. 2004. Origins and history of The Ottawa Field-Naturalists' Club, *Canadian Field-Naturalist* 118: 1-38. <https://doi.org/10.22621/cfn.v118i1.879>
Brunton, D. F. 2016. James Fletcher is designated a Person of National Historic Significance. *Trail & Landscape* 50: 40-43.
Riegert, P. W. 2000. James Fletcher, *Dictionary of Canadian Biography*. Accessed 31 January 2018. http://www.biographi.ca/en/bio/fletcher_james_131.html.

DANIEL F. BRUNTON

a casual interest into a serious passion. He largely developed his identification and remarkable field biology skills through contacting an increasingly wide circle of botanical associates in the 1860s.

In 1868 he was appointed Professor of Botany at the newly establishing Albert College in Belleville. He taught there for almost 15 years, also conducting surveys for the Geological Survey of Canada (GSC) and the Canadian Pacific Railway over several summers in the 1870s and early 1880s. Macoun



FIGURE 1. John Macoun with Geological Survey of Canada associates William Spreadborough (right) and (probably) C. H. Young (left), sorting marine specimens, Vancouver Island, British Columbia, 1908–1909. Photographer unknown.

was appointed Naturalist (Dominion Field Naturalist, in his words) to the GSC in 1882 and held that position (variously titled, including Assistant Director) until his retirement in 1911. He moved to Sidney, Vancouver Island, British Columbia for the remainder of his life. He is buried in Beechwood Cemetery in Ottawa.

Major Area(s) of Natural History Contribution

Botany (vascular plants, bryophytes, lichens); fungi; marine algae; ornithology; malacology; biodiversity documentation.

Historical Summary

While best known for his western explorations and discoveries, Macoun is the most significant collector of natural history specimens in more regions of Canada than anyone before or since his time. Perhaps dissuaded by his lack of formal scientific training or simply because of his stated preference for field work, he conducted no taxonomic investigations. Instead, he circulated duplicates of his collections widely to taxonomic authorities in the United States (there were none in Canada through most of his career) and, to a lesser degree, in Europe. Many native plants and at least one insect were named in his honour by these authorities. A number of these have stood the test of time and remain the preferred species name (Figures 2 and 3).

Macoun was an exceptionally perceptive collector with an intuitively keen eye for what was unusual or exceptional within whatever landscape he was exploring. This and the fact that his explorations were frequently conducted in primary growth (original) examples of virtually every significant non-arctic environment in Canada, resulted in the acquisition of innumer-



FIGURE 2. Macoun’s Gentian (*Gentianopsis macounii* (Holm) Ilitis) Jurra Creek, Bow Valley, Alberta, 19 September 2009. Photo: D. F. Brunton.



FIGURE 3. Macoun’s Arctic (*Oeneis macounii*) from Bonnhcere, Algonquin Park, Nipissing District Ontario, 17 June 1972. Photo: P. M. Catling.

able exceptional specimens. A travel bursary of the Canadian Botanical Association is named for him to honour that inspirational performance.

It is almost certain that more plant species are known in Canada solely from Macoun’s collections than from the efforts of any other field naturalist in history. These include the remarkable Macoun’s Shining-moss (*Neomacounia nitida* (Lindberg) Ireland; Figures 4 and 5) an endemic southern Ontario species and genus now believed to be extinct. The total of his collections is not known but even excluding duplicates, they

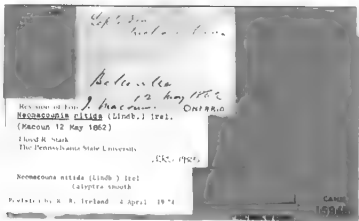


FIGURE 4. Macoun’s Shining Moss (*Neomacounia nitida* (Lindberg) Ireland), a species and genus known only from Macoun’s collections near Belleville between 1860 and 1893 and considered extinct as of November 2002 (SARA Registry 2018). Photo: Lyndsey Sharp, Canadian Museum of Nature.



FIGURE 5. Magnified image of Macoun's Shining Moss (*Neomacounia nitida* (Lindberg) Ireland). Photo: Lyndsey Sharp, Canadian Museum of Nature.

number in the tens of thousands. The Canadian Museum of Nature herbarium (CAN), now the second largest in Canada, is founded upon Macoun's massive collection of vascular and non-vascular plants. The herbarium housed over 100 000 specimens at the end of his career at the GSC.

As keen as he was on exploring and collecting native Canadian flora and fauna, he conducted virtually no field investigations outside the country. However, he was a prolific chronicler of Canadian biodiversity. His *Catalogue of Canadian Plants* was the first coast-to-coast inventory, covering all vascular and non-vascular species in a series of reports over a 20 year period. Much the same can be said of his *Catalogue of Canadian Birds* produced between 1900 and 1903, although William McIlwraith of Hamilton Ontario, Macoun's son James, and his long-time field associate William Spreadborough are likely due the major credit for the latter publication.

Macoun emphasised the practical aspects of field explorations (applied science) as opposed to pure research undertaken for its intrinsic contribution to human knowledge. He employed his field botanist insights and discoveries most famously in promoting the agricultural potential of the drylands of the Northwest Territories (today's Prairie Provinces) in a massive 1882 tome supporting the federal government's Western expansion policies and its preference for a southern route for the Canadian Pacific Railway.

Macoun was modestly involved in early efforts to generate conservation awareness. He called, for example, for protection of the extraordinary deciduous forest of southwestern Ontario in the area we know today as the Carolinian Zone. In 1893 he bemoaned that "the careless habits of the last generation" were destroying the forests of the Niagara Peninsula "so completely [that] its boasted title of the Garden of Canada would be a misnomer".

Though largely proven correct in subsequent years, his boosterism for Western development certainly exceeded what a more cautious science-based analysis would have concluded. It likely secured his appointment to his coveted position at the GSC, however, and thus established a uniquely productive career that was to last for more than 30 years. (He was less prescient in applying his field experience in parts of southern Ontario, declaring that the future of Lake Erie's Pelee Island "is not bound up in the making of wine"!).

Macoun was very physically strong and rarely ill, and many contemporaries spoke of his endurance, tirelessness, and enthusiasm as well as his remarkable memory and workaholic ways. Even with the limitations of a debilitating stroke he suffered in 1912 he continued collecting, amassing a vast collection of marine organisms during his southern Vancouver Island retirement.

John Macoun remains, simply put, the most significant collector of Canadian biodiversity ever.

References

- CBA (Canadian Botanical Association).** 2018. John Macoun Travel Bursary. Accessed 22 February 2018. <http://www.cba-abc.ca/macoun.htm>.
- Holm, T.** 1921. John Macoun. *Botanical Gazette* 71: 236–237.
- Macoun, J.** 1882. *Manitoba and the Great North-West: The Field for Investment, the Home of the Emigrant*. The World Publishing Company, Guelph, Ontario, Canada.
- Macoun, J.** 1883–1902. *Catalogue of Canadian Plants* Parts 1–7. Dawson Brothers, Montreal, Quebec, Canada.
- Macoun, J.** 1893. Notes on the flora of the Niagara Peninsula and shores of Lake Erie. *Journal and Proceedings of the Hamilton Association* 9: 78–86.
- Macoun, J.** 1900–1903. *Catalogue of Canadian Birds* Parts 1–3. S. E. Dawson, Ottawa, Canada.
- Macoun, J.** 1979. *Autobiography of John Macoun, Canadian Explorer and Naturalist 1831–1920 (Second Edition)*. The Ottawa Field-Naturalists' Club, Ottawa, Ontario, Canada.
- SARA (Species at Risk) Registry.** 2018. Species profile, Macoun's Shining Moss. Accessed 21 February 2018. http://sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=731#ot18.
- Waiser, W. A.** 2003. Macoun, John. In *Dictionary of Canadian Biography*, Volume 14. University of Toronto/Université Laval, Ontario, Quebec, Canada. Accessed 18 February 2018. http://www.biographica.ca/en/bio/macoun_john_14E.html

DANIEL F. BRUNTON and PAUL M. CATLING

Upcoming Meetings and Workshops

The Alberta Chapter of the Wildlife Society Conference

The Alberta Chapter of the Wildlife Society Conference to be held 9–11 March 2018 at the Lethbridge Lodge, Lethbridge, Alberta. The theme of the conference is: 'A Future with Renewable Energy: Implications for Wildlife Conservation with

a Special Symposium: Globalization and Invasive Species'. More information is available at <https://www.actws.ca/conference/>.

Entomological Society of America, Eastern Branch Meeting

The 89th annual meeting of the Eastern Branch of the Entomological Society of America to be held 17–19 March 2018 at the Westin Annapolis Hotel, Annapolis, Maryland. Registration

is currently open. More information is available at <http://www.entsoc.org/eastern/2018-branch-meeting>.

Entomological Society of America, North Central Branch Meeting

The 73rd annual meeting of the North Central Branch of the Entomological Society of America to be held March 18–21 March 2018 at the Madison Marriott West Hotel, Madison,

Wisconsin. Registration is currently open. More information is available at <http://www.entsoc.org/northcentral/2018-branch-meeting>.

Entomological Society of America, Southwestern Branch Meeting

The annual meeting of the Southwestern Branch of the Entomological Society of America to be held 25–29 March 2018 at the Hotel Albuquerque, Old Town, Albuquerque, New

Mexico. More information is available at <http://entsoc.org/event-calendar/esa-southwestern-branch-2018-meeting>.

US Regional Association of the International Association for Landscape Ecology Annual Meeting

The annual meeting of the US Regional Association of the International Association for Landscape Ecology (US-IALE) to be held 8–12 April 2018 at the Palmer House Hilton, Chicago,

Illinois. Registration is currently open. More information is available at <http://www.usiale.org/annual-meeting.html>.

American Ornithology Meeting 2018

The 36th annual meeting of American Ornithology and the 2nd annual meeting of the American Ornithological Society to be held 9–14 April 2018 at the Hilton Tucson El Conquistador, Tucson, Arizona. The theme of the conference is: 'Celebrating

Connections: Birds Across Borders'. Registration is currently open. More information is available at <https://amornithmeeting2018.org/>.

2018 Northeast Natural History Conference

The 18th Northeast Natural History Conference to be held 13–15 April 2018 at the Hotel Burlington and Conference Center, Burlington, Vermont. Registration is currently open.

More information is available at https://www.eaglehill.us/NENHC_2018/NENHC2018.shtml.

Annual Northeast Fish & Wildlife Conference

The 74th annual Northeast Fish & Wildlife Conference to be held 15–17 April 2018 at the Hilton Burlington Hotel, Burlington, Vermont. The theme of the conference is:

'Leading with Science for Conservation'. Registration is currently open. More information is available at <http://www.neafwa.org/conference.html>.

James Fletcher Award Established

Late in 2017, inspired by the historical reflections all around us in this 150th anniversary year of Canadian Confederation, the Publications Committee of the Ottawa Field-Naturalists' Club (OFNC) established an award to acknowledge and celebrate excellent contemporary contributions to *The Canadian Field-Naturalist* (CFN) while also honouring the historic roots of the journal. The award is named in honour of OFNC founder James Fletcher (1852–1908), who was the founding editor of the CFN's earliest iteration, the *Transactions of the Ottawa Field-Naturalists' Club*, and who also served as editor of its succeeding journal, *The Ottawa Naturalist* (later, CFN), for over a decade.

The James Fletcher Award recognizes the best paper published in CFN in a particular volume, commencing with volume 130 (2016). "Best" is often a subjective and perhaps not always fair term, especially considering the diversity of research subjects and approaches reported within a typical CFN volume. Accordingly, the ultimate choice is made from a selection of up to three finalists, all deemed particularly excellent contributions in their own right.

A subcommittee of the Publications Committee recommended suitable choices to the full committee. The full Publications Committee made the final selection.

Three finalist papers were identified for the James Fletcher Award for CFN Volume 130 (2016):

Diana Bizecki Robson, John H. Wiersema, C. Barre Hellquist, and Thomas Borsch. Distribution and ecology of a new species of water-lily, *Nymphaea loriana* (Nymphaeaceae), in Western Canada. *Canadian Field-Naturalist* 130(1): 25–31. <https://doi.org/10.22621/cfn.v130i1.1787>;

an extensive field investigation of the distribution and ecology of a newly described aquatic plant species endemic to the Prairie Boreal Region of Canada;

Robert G. Forsyth, Paul Catling, Brenda Kostiuk, Sheila McKay-Kuja, and Allen Kuja. Pre-settlement snail fauna on the Sandbanks baymouth bar, Lake Ontario, compared with nearby contemporary faunas. *Canadian Field-Naturalist* 130(2): 152–157. <https://doi.org/10.22621/cfn.v130i2.1839>

– a combination of contemporary field work and forensic lab analysis compares snail diversity detected within a deposit of 1000+ year old specimens against the current diversity at this lakeshore sand dune site;



Peter B. Mills and Duncan J. E. Hill. Ancient lake maxima and substrate-dependent riverine migration have defined the range of the Mudpuppy (*Necturus maculosus*) in southern Ontario following the Wisconsinian glaciation. *Canadian Field-Naturalist* 130(2): 158–163. <https://doi.org/10.22621/cfn.v130i2.1840>

– a large body of data gathered co-operatively through the Ontario Herpetological Atlas is combined with regional geographic/biogeographic information to hypothesize probable post-glacial migration routes.

The paper "Distribution and ecology of a new species of water-lily, *Nymphaea loriana* (Nymphaeaceae), in Western Canada" was selected from these finalists as the first recipient of The James Fletcher Award. It represents foundational research on a new taxonomically important species and will be referred to for decades to come.

Congratulations to authors Robson, Wiersema, Hellquist and Borsch, who have been sent personal copies of the award certificate (Figure), and to the other finalists. We are pleased to take this opportunity as well to express our appreciation of all authors who chose to share their valuable field-based research findings with the readers of *The Canadian Field-Naturalist* Volume 130.

DANIEL F. BRUNTON and JEFFERY M. SAARELA
OFNC Publications Committee

Book Reviews

Book Review Editor's Note: *The Canadian Field-Naturalist* is a peer-reviewed scientific journal publishing papers on ecology, behaviour, taxonomy, conservation, and other topics relevant to Canadian natural history. In line with this mandate, we review books with a Canadian connection, including those on any species (native or non-native) that inhabits Canada, as well as books covering topics of global relevance, including climate change, biodiversity, species extinction, habitat loss, evolution, and field research experiences.

Currency Codes – CAD Canadian Dollars, USD US Dollars, EUR Euros, AUD Australian Dollars, GBP British Pound.

BOTANY

Curieuses histoires de plantes du Canada. Tome 1: 1000-1670, Tome 2: 1670-1760, Tome 3: 1760–1867

By Alain Asselin, Jacques Cayouette, and Jacques Mathieu. 2014, 2015, 2017. Septentrion. 288, 328, 312 pages, 44.95, 49.95, 49.95 CAD, Paper.

When early explorers from Europe came to Canada they found not only a new land, but also a new flora comprised of many plants they had never seen or heard of before. During these early explorations plants were sent back to Europe so that botanists could study them or grow them for food or medicine. For these first modern botanists it meant making many new discoveries. Some more adventurous botanists even made the trip across the ocean in the hope of finding new species. The native people who inhabited the land centuries before taught the newcomers about many useful plants, and even saved their lives by showing them how to use a mysterious plant potion they called Annedda to cure them from scurvy. However, early botanists wanted to describe and name the new plants according to the botanical knowledge of their scientific culture. The difference between traditional and scientific plant knowledge as well as the science of botany, which was still at its infancy, sets the scene for many fascinating stories.

Curieuses histoires de plantes du Canada is a series of books describing interesting botanical and historical facts of Canadian plants. Many botanical discoveries were made during important historic events that defined Canada. These events are recounted in these books with emphasis on plants or plant particularities that were discovered contemporaneously. The three recently published volumes are divided according to important milestones in Canadian history. The first volume contains stories spanning the time frame from the first Viking explorations to around the beginning of the Hudson Bay Company. Volume two takes place during the French rule period, while the third volume takes place during the British rule period until the time of confederation. Each volume is divided into multiple short stories presented in chronological order. Each story provides the reader with the necessary historical context at the time of these botanical discoveries and

describes what was known about the plants at that time. The stories also highlight specific points about the people and circumstances leading to the discoveries.

It is interesting to see how botanical knowledge evolved through time. Of frequent interest to readers may be the historical medicinal values and other beneficial properties of plants. One example is Bloodroot (*Sanguinaria canadensis*) which was once used as toothpaste and mouthwash. It was proven that Bloodroot does not have any effects against dental plaque or gingivitis but there may be antimicrobial and antitumor properties that have yet to be discovered. Another interesting story explains an easy recipe which was used to test for food adulterants in flour. By placing a small quantity of flour in a glass of water and adding sulphuric acid, it was possible to evaluate for impurities. If the flour was pure, the sulphuric acid would consume all of it. Adulterants would have been clearly visible after 10 minutes because they would not have been consumed. In addition, materials such as lime would cause the mixture to fizz. Some other stories relate interesting anecdotes behind plant names. Some stories convey information on the persons who named the plants and others on who they were named after. One example is the story about Sir Joseph Banks, a famous English naturalist with connections to the Canadian railway system. As a matter of fact, *Pinus banksiana* was named in honour of his legacy and it happens to be one of the most commonly used timber in the production of railway ties in Canada. These books contain many more stories, all sharing with the reader curious and intriguing facts about plants.

This book series is both pleasant and interesting to read. It is beautifully edited and includes many appealing botanical and historical drawings of great aesthetic and scientific value. Numerous text boxes provide more detail on various aspects present in the stories. Exten-

sive botanical and historical research documents each story and references are provided either at the end of every story or even at the end of each text box. Recent scientific literature references are also used to provide a contrast with the knowledge of our ancestors, or in some cases to confirm their beliefs and findings. Because nomenclature has changed a lot through time, the authors use modern nomenclature to identify the organisms in the books; the plants are referred to with their original names and verified with those now accepted in VASCAN (data.canadensys.net). Looking back in time, some plants were initially thought to be something completely different from what is known today. However, we must also admit that how information on plants is now captured has evolved greatly, though sometimes at the expense of ancestral knowledge about the plants with whom we coexist. The stories narrated in these books help revive countless facts that are generally overlooked in botanical textbooks.

I recommend reading the books if you are interested in plants and you enjoy history. Furthermore, it is an essential read for anyone wishing to learn more about the cultural aspects of Canadian plants. Because all the books contain short stories, it is easy to take breaks be-

tween stories and continue later. As well, I think that readers who don't read French books can cope with the challenge of reading these books. The effort of understanding the text is worth it. One can also learn many things just by flipping through the books, reading the titles, and looking at the illustrations. These books have synthesized centuries of historical knowledge relevant to plant sciences from a vast array of sources, and it is ultimately worth reading them in detail. The three currently published volumes constitute a very good reference on early botanical science. The books are easily searchable, whether one is looking for information on a particular plant, on medicinal properties, on a specific locality, or on a botanist, via a very detailed index. For anyone doing research on Canadian plants or wishing to learn more about them, these books provide subtle details that allow one to enrich their existing knowledge of these plants. I am looking forward to the next book(s) in the series to learn how contemporary botanists have contributed to botanical science and what twists the authors will take to make the more recent plant stories interesting to read.

ALEXANDRE BLAIN

Gatineau, QC, Canada

ENTOMOLOGY

The Secret Life of Flies

By Erica McAlister. 2017. Firefly Books. 248 pages, 29.95 CAD, Cloth.

When was the last time you really, truly looked at a fly? Admired the shimmery blues and greens of a Housefly (*Musca domestica*) before swatting it away from your dinner? Gawked at the Stalk-Eyed Fly (*Achias rothschildi*) as it swallows air to inflate its own eyes (think bicycle pump)? Step inside the brain of Erica McAlister, the Senior Curator for Diptera at the Natural History Museum in London, United Kingdom, and you will see flies for what they are: an order of species with astonishing diversity, usefulness, and beauty.

Imagine the most enthusiastic teacher you've ever had, and you get close to the experience of reading this book. The writing is liberally peppered with exclamation points, and it is infectious! There are enough jaw-dropping fly facts in here to catch the attention of any reader who wants to know more about the natural world. Truly, Diptera are lucky to have such a passionate advocate in McAlister. As she rightly points out, too often are flies, and insects in general, ignored by "mainstream conservationists" in their campaigns to protect the charismatic macro-fauna. Where, she argues, is the campaign to save the endangered Bee Louse (*Braula coeca*) that has not been seen in the United Kingdom for years? When was the last time you expressed concern for the Rhino Bot Fly (*Gyrastigma rhinocerontis*), which may be one of the most threat-

ened species of animal on the planet? If we will only conserve what we love and only love what we know, then let this book become your guide to giving flies the respect they are due.

Flies are often underappreciated, but they are essential to our daily lives. They pollinate many economically and culturally important crops (thank a fly from the *Forcipomyia* genus the next time you enjoy chocolate!), control other insects that are agricultural pests, are a food source for animals that we enjoy watching, such as birds, and do an excellent job of decomposing plant and animal waste.

However, McAlister does not spend all her time trying to convince the reader that flies are only worthy of our attention because of their usefulness to humans. She constantly regales us with descriptions of how fascinating these animals are as objects of scientific study. The Gray Bee Fly (*Anastoechus melanohalteralis*) is "possibly the cutest animal on the planet" (p. 205); horse flies often have "the most spectacular bands, squares, triangles, circles and wiggles on their eyes" (p. 216), and parasitic flies "are some of the most extreme in terms of modifications from the basic plan, which of course leaves even the most experienced of dipterists with feelings of childlike pleasure" (p. 211). These descriptions made me simultaneously feel like

I was missing out by not being a dipterist, and glad that I had been pulled along for the ride in this joyfully written book.

McAlister has divided her book into 10 chapters based on functional feeding type, such as the Pollinators, the Coprophages (the eaters of animal waste), the Vegetarians, the Parasites, and the Sanguivores (blood-suckers like mosquitos and black flies). Within these chapters McAlister nimbly jumps among species and anecdotes that connect flies to history, medicine, agriculture, forensic science, conservation, and even pop culture. One of my favourite passages is a rant about the use of a dinosaur-DNA-filled adult crane fly in the opening scene of the original Jurassic Park movie. Adult crane flies, as I learned, do not possess the mouthparts to pierce the skin and would therefore never be filled with another animal's blood. So egregious is the error that "many a performance must have been disrupted due to excessive tutting by indignant dipterists" (p. 129), and now you too can join in the indignation. It is precisely this commitment to connecting flies to our daily lives in a way that inspires an "Oh neat!" rather than an "Oh gross!" that makes this book so engaging and worthwhile.

Here's something to ponder the next time you're getting chewed on by mosquitos in a bog: did you know that there are species of mosquito whose larvae live inside the water body (the phytotelma) of pitcher plants? Older plants produce less of the digestive enzyme needed to break down insect material. The mosquito larvae, in the midst of their feeding frenzy in the belly of the pitcher plant, leave behind finely shredded insect remains that are more accessible to the smaller supply of enzymes available in older plants. At the very least, reading this book will leave you with many such neat facts for your next nature hike or cocktail party.

I hope *The Secret Life of Flies* will bring you more than fodder for small talk. It has the power to inspire you to pay closer attention to all the small things around us, like the mosses, plankton, insects, bacteria, and fungi that collectively make the world work in ways we don't understand. As naturalists, ecologists, and conservationists, we should strive to learn as much as we can about all life, and McAlister's engaging look into the world of flies is a great place to start.

EMMA BOCKING

St. John's, NL, Canada

Insects: Their Natural History and Diversity: With a Photographic Guide to Insects of Eastern North America, Second Edition, Revised and Updated

By Stephen A. Marshall. 2017. Firefly Books. 736 pages and 4000 colour photographs, 95.00 CAD, Cloth.

Entomology is a huge topic and this, as are Stephen Marshall's previous books, is a huge book. The numbers above say as much, but here's another one: it weighs just over three kilograms! Clearly not a field guide, but very much a guide to the fields explored by naturalists. And if you want an entomology course—something that is increasing difficult to find, given the decline in the number of courses—without the bother of attending classes, then this is your book. Marshall has been teaching entomology in the University of Guelph's Department of Environmental Biology since 1982 and the two editions of *Insects* are the distillation of that experience. In fact, as he explains in the new preface, their text varies little, with this edition primarily updating the ever-shifting taxonomy of the insect world. Marshall describes the decade following the first edition as "tumultuous" and the taxonomy as "transformed by ... application of new molecular tools..." (p. 7). However, his "tree of six-legged life" remains unchanged, for "the main phylogenetic roadmap ... has been substantiated, not redrawn" (p. 7). If you already own the first edition, there may not be enough difference here to justify the expense of the second, so long as you don't mind being out of date on the taxonomy and missing out on the new photos. But if you don't own the first, then your entomological library won't be complete without this one.

The roadmap may be the same, but the landscape it guides us through is changing: new species, introduced inadvertently or deliberately and often invasive, have become established; extinction rates are too high and rising; climate change increasingly forces ecological change. Meanwhile, we do not know enough to describe and evaluate these changes accurately. And so, Marshall aims this edition at naturalists, in the hope that while exploring our locales, we will gather and share information about the changes we witness: his explicit call for engagement in citizen science is reiterated at various places throughout.

The Introduction provides an overview of the definition of an insect and its general morphology plus the "tree" of insect life. The 11 chapters forming the body of the book are organized around the common names of several insect orders, bracketed by Chapter 1 on the earliest insects and Chapter 13 on other arthropods, such as spiders and millipedes. A final chapter provides an excellent, succinct overview of "Observing, Collecting and Photographing Insects". Each chapter consists of text organized around the families under discussion, followed by copious photos illustrating the many species within these families. The photos—an integral, essential part of the book—are a reasonable size, 44 × 58 mm, and usually nine to a page. Organized like the text, but in more taxonomic detail, the photos and their

captions—which contain additional details on the size, range, habitat, and behaviour of the species pictured both illustrate and supplement the main text. Marshall is a prolific photographer and this edition is, in part, a celebration of the advances in digital photography, “the game changer” for “most naturalists” (p. 7). He started using photos in his courses 30 years ago in the days of slide film; many new photos in this edition are digital. The photos were taken over several decades of travel and concentrate mainly on northeastern North America.

Chapter lengths vary with the size of the orders discussed. Thus, Chapter 3 on Stoneflies is a mere six pages, Chapter 8 on Caddisflies is 10. Similarly, the chapters on the five largest orders, Hemiptera, Lepidoptera, Coleoptera, Diptera, and Hymenoptera, are long and involved. The longest is 11, “Flies, Scorpions and Fleas”, at 167 pages, a mere summary of his 2012 volume, *Flies: The Natural History and Diversity of Diptera* (Firefly Books). A description of the order is followed by its main subcategories, generally down to family and sometimes genus. It seems every page is punctuated by fascinating details of insect characteristics and behaviour, recounted in his approachable style, leavened by his sense of humour. Only a brief sample can be mentioned here. Did you know that owl moths can detect the clicks of bats, and that the mites that live in these moths’ ears choose only one ear so as to enable the moths to continue evading the bats, protecting both moth and mite (p. 175)? Or that our single species of bess beetle (Passalidae) has 14 distinct calls (p. 269); that male dance flies provide nuptial gifts to prospective mates (p. 399); an ingredient for secret ink was first found in oak galls (p. 524); or how maggots are like whales (p. 401)? Didn’t think so!

Retaining so much of the original text makes sense for several reasons, but a light editorial hand could have checked, for example, all the unchanged uses of the word “recent” and similar expressions, or updated occasional time-based references, such as a canoe trip 30 years ago mentioned in both editions. Occasional more important updates have been made, for example, predicted dates for mass appearances of cicadas (pp. 102–103). And, while I’m quibbling anyway, one large family appears in the photos, but not the text (Lepidoptera: Notodontidae, the Prominents; pp. 225–229). These are minor points, however, for most readers aren’t going to check both volumes and the second edition text doesn’t sound or feel dated.

The back matter remains relatively unchanged from the first edition: website information has been updated (for the most part), including note of the invaluable work in the open, online *Canadian Journal of Arthropod Identification* (<http://biologicalsurvey.ca/cjournal/>), with which, he modestly omits to say, he is heavily involved. Several references have been added to the bibliography; two new “simplified” picture keys have been added to the original two dozen: one on insects that hurt and one on species found indoors. The picture keys are an important part of the book, illustrated by sketches and generally using familiar terms. Three indexes are provided, to the photographs by genus and species, to common family names, and a general, largely taxonomic, index; its updates reflect, of course, the many taxonomic changes. That might seem like overkill, but there is a lot to navigate in this book!

The simple statistics of the book indicate how impossibly large the field of entomology is. Scientists can spend entire careers collecting and organizing chosen families of insects. Stephen Marshall has made heroic efforts in this and previous publications to distill this extensive knowledge into a useful, accessible format. While the book is far too big and heavy to cart into the field, it is invaluable in the home office—preferably on a lectern!—for anyone interested in learning more about these fascinating animals. While the first edition was produced initially as a text for his third-year entomology course, the second adds another purpose: to not only teach insect identification, but also to encourage potential citizen scientists to contribute to their own as well as a broader understanding of entomology. This is a never-ending task, and the sheer number of people Marshall acknowledges (p. 677) as helping along the way is another measure of its enormity. This book, then, is in a sense an iterative process: it accumulates much of what is known, comments on how little that really is, and encourages the expansion of knowledge. If it’s successful, the second edition will necessitate its replacement by further editions as well as, we can hope, more specialized off-shoot volumes, such as *Flies*, for other large orders. We’re behind in Canada compared to other countries. We may never catch up, but we can at least be inspired to get into the game. *Insects: Their Natural History and Diversity* is a great source of such inspiration.

BARRY COTTAM
Ottawa, ON, Canada

ORNITHOLOGY

Raptors: The Curious Nature of Diurnal Birds of Prey

By Keith Bildstein. 2017. Cornell University Press. 336 pages. 52.50 USD. Cloth.

Reading this book on raptors was like reading Lady Diana’s biography. We have seen the pictures and much of the text before. Pulling all the many reports together

in one place provides a clarifying perspective on a very complex subject. This is the case with *Raptors*. I have heard much—but not all—of the information before,

in bits and pieces and separated by years. Bildstein has done a great job of combining all the information into one volume. The author has excellent credentials for this undertaking. He is the Sarkis Acopian Director of Conservation Science at Hawk Mountain Sanctuary in Pennsylvania. He organises the conservation and education programs and runs the graduate, international, and visiting scientist programs. He has authored many peer-reviewed publications including several books on raptors.

Many years ago, I was confused by the question of what is a raptor? Is it a meat eater? American Robin (*Turdus migratorius*) and Golden Eagle (*Aquila chrysaetos*) eat meaty worms. Mergansers and Osprey (*Pandion haliaetus*) eat fish. Clearly robins and mergansers are not raptors. How about birds that catch prey in their talons? Where does this leave vultures? I am relieved to note I am not the only one confused. Even the mighty taxonomists seem to be in a quandary. This author notes that the American Ornithological Society (AOS) lists woodpeckers, falcons, and parrots in sequence. However, he says it should be tyrant flycatchers, parrots, and falcons. Similarly, the AOS has hawks, owls, and trogons together, while the author quotes molecular research as grouping owls, North American vultures, and the Cuckoo Roller (*Leptosomus discolor*). Our own Turkey Vulture (*Cathartes aura*) is another enigma. It is not a buzzard and is not related to the raptors of Europe, Africa, and Asia. While the New World vultures look like their old-world counterparts and perform the same ecological role, it is the result of convergent evolution, not family ties. Taxonomists seem to have difficulty deciding who the Turkey Vulture's closest relatives are: ibis, owls, or the enigmatic Cuckoo Roller; no wonder I am confused. I will stay happy to count all the hawk-like birds as raptors.

For me the author has two achievements. Aside from bringing an over-arching outlook, he also brought a

global perspective. He does a really fine job of covering raptor biology, at least what we know so far. He has researched how a raptor is put together and the effect on feeding, breeding, flight, distribution, and migration. He notes the many deficiencies in our knowledge and the possible ways we can fill the gaps (with webcams, satellite tracking, miniature transmitters, etc.).

I thought I understood migration, but Bildstein shows it is way more complex than we ever knew. The recently-discovered meanderings of Turkey Vultures are confusing. The amazing migration of Amur Falcons (*Falco amurensis*) is truly startling. I have seen these delightful little raptors breeding in Mongolia and wintering in Africa without realising how tough they are.

There is a small section of photographs. While they are good quality, I suspect they were chosen to illustrate a point rather than provide heart-stopping photos.

I found the chapter on "Raptors and People" the most enlightening and disturbing. The list of offences, both deliberate and unthinking, we have committed against these birds makes for unsettling reading. It is remarkable how they have survived this onslaught, but they still need our help. Despite taking four trips to India, I have seen just over 150 vultures of all species in a country where there used to be 40–50 million birds. In North America, the number of times bounties have been paid for raptor heads is horrifying. We are still not over the anti-raptor hurdle and it is comforting to know there are still people working to save these magnificent birds.

While most avid birders will be in familiar territory, the book reveals some interesting twists. It is easy to read, yet still maintains a very high level of scientific objectivity. I learned a lot, as well as refreshing some of the grey zones in my aging brain. Most importantly, I enjoyed reading this book.

ROY JOHN

Ottawa, ON, Canada

The Australian Bird Guide

By Peter Menkhorst, Danny Rogers, Rohan Clarke, Jeff Davies, Peter Marsack, and Kim Franklin. 2017. CSIRO Publishing. 576 pages, 49.95 AUS, Paper.

Technically, I had been to Australia in 2013. My single day on Macquarie Island in 2013, over 2000 km south of Melbourne, did not prepare me for the overwhelming barrage of new species and genera when I reached the mainland in 2017. What better to assist me to plough through this confusion than a brand-new field guide. And what a guide!

Australia, plus its offshore territories, has a list approaching 900 species, almost half of which are endemic. This new guide has around 4700 colour illustrations depicting over 900 species and covers all the distant islands. The authors include everything, from full coverage of vagrants to remote island territories and species known only as washed up bodies. Each species has illustrations of adults, juveniles, females, dark and light morphs, and summer and winter plumage as ap-

propriate. When necessary, birds are shown in flight. These depictions are not just accurate, they are beautiful. It is very useful to have the variation in plumages depicted, especially for a novice. So often the bird you see does not quite "fit" the book. Having multiple choices helps when you find a bird like a cuckoo-shrike. There are four similar species of cuckoo-shrike and having minor details helps narrow the choice. Also, the Australasian Figbird (*Specotheres vielloti*) has two subspecies (*S. v. vielloti* and *S. v. ashbyi*), both accurately depicted, and I saw both. My notes are such that if the taxonomists split these two into full species I will be able to count an armchair tick.

The illustrations are accompanied by text that is more informative and expansive than a typical guide. This comes at a price. The book is 18 × 25 × 3.3 cm

and weighs a whopping 1458 g. It is not a field guide. My copy of the 2004 *Field Guide to the Birds of Australia* by Simpson and Day is 80% lighter and fits my coat pocket. With the text are clear, readable range maps. These combine to provide better insight into the identification choices you can make.

I was with a non-birder companion when she said the call we had just heard was a wattlebird. I searched and had a very good look at a mid-size, streaky bird. I looked in the new guide for “wattlebird” and could not find an entry. I vaguely remembered that wattlebirds were close to miners, but there was no entry for miners either. By page flicking I found my bird: a Little Wattlebird (*Anthochaera chrysoptera*). I then realised the index does not group birds in the classical fashion (Wattlebirds —, Western Little, Red and Yellow). You need to know the full name—Little Wattlebird—before you can use the index. I found this both confusing and strange.

We continued our walk and saw a large flock of black-coloured cormorants with a single black and white bird in the group. This time, knowing there was a species called “Pied Cormorant”, I easily found the cormorant page. I had four choices. I eliminated one by range. Neighbouring birds gave me a good idea of length. Yet the authors do not include length, only weight. I cannot estimate weights in the field. (Remember a Great Horned Owl [*Bubo virginianus*] is 30% shorter than a Great Grey Owl [*Strix nebulosa*], but 30% heavier). In frustration I returned to my old copy of Simpson and Day. I identified my bird as a Little Pied Cormorant (*Microcarbo melanoleucos*).

ZOOLOGY

Wolves of the Yukon

By Bob Hayes. 2010. *Wolves of the Yukon* Publishing. Druckerei Fritz Kriechbaumer. 278 pages, 27.99 CAD, Paper.

Wolves of the Yukon was an engaging and highly enjoyable, easy read with a simple but most accurate book title. While I have never been to the Yukon, this paperback put it on the map as one of my bucket list destinations. It is an area that is pure wilderness, with Moose (*Alces americanus*) and Caribou (*Rangifer tarandus*) outnumbering people 10 to one and one Gray Wolf (*Canis lupus*) for every five humans (p. 125). My basic research on the Canadian Territory (i.e., Googling it) showed that today there are about 35 000 people living there and given that there are 5000 wolves inhabiting the region (pp. 102, 118, 126, 170, 251), the ratio is now more like seven to one. Nonetheless, this Territory is about as pristine as a large area gets with an amazing lack of people living in “the very last remaining mountain wilderness of North America” (p. 10). It is an area dominated by many of the large mammal inhabitants which have been there since the Pleistocene over 10 000 years ago.

Bob Hayes researched wolves in the Yukon for nearly 20 years from 1982–2000. He radio-collared hun-

I continued to use Simpson and Day out in the field. Each evening I would read up in Menkhorst *et al.*, as it provided more information. Sometimes, however, I wondered about the text. I spent a glorious day with a woman who was working hard on her Australia list. She had been to out-of-the-way (expensive) places like Macquarie and Heard Islands. Heard is the best place to find the resident Black-faced Sheathbill (*Chionis minor*), an endemic species. Yet Menkhorst *et al.* list it as a very rare vagrant with only one record. In contrast, they accept the tiny breeding colony of Common Redpoll (*Acanthis flammea*) on Macquarie as a resident species.

After I reached home I discovered there was a quick reference to bird families on page vi. This was very useful as I identified my photographs. I wish I had noticed it in the field. There was a visual quick reference on the inside cover. I could not use this effectively as I did know many of the bird shapes.

Overall, this is a wonderful book. The information and superb illustrations make it a tremendous contribution to the world’s bird books. Adding an index that would work well, editing some of the odd text, and relabelling it a “handbook” would turn it into the true triumph it ought to be.

ROY JOHN

Ottawa, ON, Canada

Literature Cited

Simpson, K., and N. Day. 2004. *Field Guide to the Birds of Australia*, 7th Edition. Princeton University Press, Princeton, New Jersey, USA.

dreds of wolves, pioneering research on the kill rate by wolves of Moose, Dall’s Sheep (*Ovis dalli*), and woodland and migratory Caribou. He also studied the effects of wolf control on wolf and prey populations, guiding original research on non-lethal ways of controlling predation. He came to understand many aspects of wolf biology, including pack dynamics, reproduction, food habits, kill rates, dispersal, den selection, scavenger competition, and cause and rate of mortality (p. 247).

Using a combination of narratives and easy-to-follow essays, Hayes traces the history of the Yukon wolf from the end of the Ice Age to the present day. Each chapter begins with a vignette or field experience that relates to the theme of the chapter. In the first couple of chapters, which starts 20 000 years ago on the Mammoth Steppe, we learn about some now extinct animals such as the Giant Short-faced Bear (*Arctodus simus*), Woolly Mammoth (*Mammuthus primigenius*), and Yukon Horse (*Equus lambei*; a perfect prey item for wolves back in that epoch), among others, that lived in Beringia, a vast treeless plain or steppe resembling the high grassland

plateaus of Mongolia today (p. 21). The beginning of Chapter 1 painted the scene of a pre-historic pack of wolves hunting Caribou and losing their carcass to an enormous Giant Short-faced Bear. It was highly captivating. The first seven chapters, all in the section "History", started with fictional events but were based on real-world experiences that the author has had with modern-day wolves which haven't changed much since the Pleistocene (p. 20). The chapters then described ecological conditions since the most recent glaciation and include the relation between ancient and modern native people and wolves. Chapter 5 is set in the late 1800s and here we learn about the importance of Jack London's and Robert Service's writing and the linking of wolves and wilderness, especially the Yukon region. I thought that the first section of the book did a great job of setting the stage for the second—and longer—section.

The second of the two parts of *Wolves of the Yukon*, "Understanding", included nine chapters on Bob Hayes' research. The beginning chapter stories in this section were based on his or his colleagues' field notes and explored his original investigations into wolf relations to Moose, Caribou, Mountain Sheep (*Ovis canadensis*), Ravens (*Corvus corax*), Grizzly Bears (*Ursos arctos*), and human hunters. Hayes does an admiral job of describing the importance of radio-telemetry to studying wolves and gives many engaging accounts of him darting wolves from helicopters (pp. 154–164). He described finding uncollared wolves as searching for the proverbial needle in a haystack (p. 163). I couldn't stop reading that chapter (9)! Using radio-telemetry, Hayes found that, despite humans killing them liberally, wolves were the number one cause of death of other wolves (p. 163). In section two, we discover that Moose are the "perfect prey" (Chapter 10) and that wolf numbers throughout the Yukon most closely parallel Moose distribution with abundance and pack sizes being bigger (> 10) in areas with increased Moose densities (p. 137). In fact, Yukon wolves are some of the largest in the world because of their reliance on this large prey item (pp. 56, 171). I also learned that, although wolves mostly kill young and old (i.e., not prime-aged) Moose, most are healthy and in good condition (p. 177).

Chapter 11 describes many exciting encounters between wolves and Dall's Sheep in highly remote, pristine, mountainous regions. However, neither Hayes nor his associates ever witnessed an actual sheep kill by wolves (p. 189). And because sheep live in steep and dangerous areas, wolves have little effect on their populations (p. 194). In fact, wolves that rely on sheep live in small, unstable packs (p. 195). The next chapter (12) describes some very interesting behavioural observations of wolves in the Arctic region of the Yukon. There they are vagabonds and have no fixed territory because of the migratory nature of their main prey, Caribou (p. 201). This behaviour remains the norm for northern wolf packs until one goes south and into the taiga region where the presence of Moose provides a food-base for wolves to live year-round on territories (p. 203).

In the remaining chapters (13–15), also highly absorbing, we learn that Muskrat (*Ondatra zibethicus*) and other small animals are important summer foods (pp. 214–215) and that fish, even in the winter, are important to some packs (pp. 215–217), which can have the added benefit of taking pressure off Moose and Caribou. Ravens are easily the most important scavengers of wolf kills (pp. 223–225), especially for small packs or pairs where the birds can remove impressive amounts of meat from a carcass (pp. 225–228). There was a fascinating description of Ravens aggressively attacking a pair of wolves even while Hayes was trying to dart the wolves for collaring purposes (pp. 230–231). And, what would a book about wolves in the far north be without including a chapter (15) on bear-wolf relations? While they are mutual enemies, it is rare for them to kill each other, although it does happen, as Hayes vividly describes (pp. 238–240).

The last chapter of *Wolves of the Yukon* tells why broad-scale killing of wolves to increase game should ultimately end. Hayes believes that it is cost inefficient and biologically and morally wrong and, ultimately, short term in nature as wolves recover quickly from control actions (pp. 249–251). Here we learn that fertility control works best in reducing predation pressure and is a much more publicly accepted, non-lethal wolf management technique (pp. 253–255). He raises profound arguments about how to value and conserve the largest remaining tract of complete wilderness on the continent, poignantly stating that "Despite the constant challenges the wolf has faced since the Pleistocene it has endured and succeeded in becoming the primary force shaping the Yukon wilderness today. It has survived prey extinctions since the ice age... In the last hundred years the Yukon timber wolf has recovered from trapping, hunting, bounties, poison, and aerial control campaigns. Despite this persecution the wolf has endured... with as many wolves ranging through the Yukon today as thousands of years ago" (pp. 258–259). To this end, Hayes can be credited for contributing to the *Yukon Wolf Conservation and Management Plan* (2012, Environment Yukon), which assures that wolves have a right to live in the Yukon and that hunting laws value wolves as a big game animal, and for researching non-lethal methods to control wolf numbers (p. 253).

I really enjoyed this book. Despite being 278 pages, it was a relaxed and quick read. Because it was self-published, I did notice a dozen or more errors, but these were all very minor and easy to interpret (and ultimately to fix with a potential new edition). There was no index at the end of the book which prevented searching for specific information unless you kept notes (which I did), but there was a nice bibliography including many of his papers. I found it interesting that Hayes often referred to wolves in the Yukon as timber wolves which I thought was a term for wolves well to the south. There were many maps throughout the book including a pull-out on the cover insert and at least one per chapter. I found these immensely helpful in relating to a region that I have yet to visit. Kudos to Bob Hayes, who had a

great 20-year research career and gave the world a gift by putting in the effort to make this self-published book available for all who want to learn about wolves living in one of the most remote regions of the world. Well done!

JONATHAN (JON) WRAY

Eastern Coyote/Coywolf Research, Osterville,
MA, USA

OTHER

Rise of the Necrofauna: The Science, Ethics and Risks of De-Extinction

By Britt Wray. 2017. Greystone Books/David Suzuki Foundation. 288 pages, 26.95 CAD, Cloth.

This book is about the recreation of extinct species through genetic engineering. It addresses how it might be done, what species might be targetted, and the various practical problems entailed. It also reviews at some length why we would want to do it, and the various pros and cons of such resurrections. The book grew out of a couple of radio broadcasts the author had created on the same topic and I realised, after starting to read it, that I had heard one of them, on the CBC "Ideas" programme, a year or so back and had been very impressed with the open, but quizzical, way in which the host (the author) had addressed the topic.

In the introduction, the author quotes the biologist, Stan Temple, as saying de-extinction is "...a game-changer for the conservation biology movement", because it overturns one of the main driving forces behind species conservation, "extinction is forever" (p. 6). The author suggests that there is a danger we might reduce our concerns about species extinction if we feel we can resurrect them when conditions improve. She quotes Stuart Pimm as calling it a "moral hazard" (p. 72). Unsurprisingly, scientists working on projects related to de-extinction do not feel that way.

The field of de-extinction studies is not a huge one right now. This is because (a) the technical problems in species resurrection are formidable, (b) many species have disappeared because we destroyed the ecosystems they were part of, and there seems little point in resurrecting them unless we can simultaneously restore their native habitat, and (c) large fierce animals, which are charismatic enough to attract the necessary funding, often threaten other interests (farmers, foresters, the public at large) and their resurrection may not be greeted with universal enthusiasm.

Wray devotes much text to two cases where de-extinction has been mooted: the Passenger Pigeon (*Ectopistes migratorius*) and the Woolly Mammoth (*Mammuthus primigenius*). Passenger Pigeons were the most abundant birds in North America in the pre-European period. They fed principally on tree seeds and must have had a huge impact on forest ecology at the time. Woolly Mammoths trampled and cropped the tundra ecosystems of the Pleistocene and it has been argued that their efforts were crucial in maintaining grasslands. Hence, both species were probably essential to their ecosystems, and their resurrection and spread might help to restore many aspects of early ecosystems that have been lost. Certainly, the idea of restoring either or both has a huge emotional appeal.

As in her radio programme, Wray is skeptical about the true value of de-extinction in this book. She feels that the techniques developed may be more useful in preventing extinction of still extant species than in creating "necrofauna". Is this a topic that we, naturalists and conservationists, should be deeply concerned about? That is not the message of the book. Rather, the author uses the concept of restoring extinct species as a basis for discussing a variety of conservation choices. Should you read it? All seven reviews currently on Amazon give it five stars. The writing is engaging and there is lots of interesting information, but I did not get the feeling that this is something the thinking conservationist must know about. No doubt at some stage in the future some species will be resurrected, if only because of the fame that will attach to their re-creator, but right now there are probably much more important problems out there to be wrestled with.

TONY GASTON

Ottawa, ON, Canada

The Magnificent Nahanni: The Struggle to Protect a Wild Place

By Gordon Nelson. 2017. University of Regina Press. 304 pages, 34.95 CAD, Paper.

Most of us have seen images of the Nahanni River region, of the Rabbitkettle tufa mounds, Virginia Falls, canyon walls towering over rafts and canoes, or the jagged peaks of the Cirque of the Unclimbables. While Gordon Nelson's *The Magnificent Nahanni* includes

a few excellent photos (30) of these icons, this is neither a coffee table photo book nor a guidebook. But if you are looking for a comprehensive history of the four-decade struggle to protect this biologically and culturally rich area, then this is the right book.

The book is separated into three parts, each of which has two to four chapters. Those are followed by two appendices (one a note on sources and the other a list of traditional place names in the Dene language), 21 pages of chapter-by-chapter notes, 15 pages of references, and an index. Fifteen maps of various scales were appropriately chosen. Nelson brings a scholarly approach to his subject, having published numerous papers, reports, and books in the fields of land use, environment, and planning, with special emphasis on national parks. However, his writing style is mostly very approachable. Interestingly, although he has been involved with the area since the early 1970s (at that time he was president of the National and Provincial Parks Association, precursor to the Canadian Parks and Wilderness Society), Nelson did not do a Nahanni River trip until 2013!

Nelson begins Part I with a brief introduction to the natural wonders of the Nahanni area (expanded upon in Chapter 2), introducing the reader to Raymond Murray Patterson, a young Englishman who trapped and prospected in the lower valley in the late 1920s and much later wrote *The Dangerous River: Adventures on the Nahanni* (George Allen and Unwin), first published in 1954. Patterson was the first person to propose conservation of the area, and Nelson refers to Patterson's observations throughout the book. After setting the wild stage, Nelson does a rather abrupt segue to discussing the prevailing concept of wilderness being pristine, uninhabited land, which left First Nations out of early park discussions, and their recent involvement in park expansion. In the early 1970s there were two fundamental policies to creation of a national park: that the federal government should ultimately own all the land in the park, and that it should be planned and managed as "pristine", i.e., devoid of past or present human activity: both policies led to indigenous opposition. The formation of the small core area as a national park reserve in 1976 indicated postponement of the ownership question until settlement of aboriginal land claims by the Dehcho and Sahtu First Nations. In Chapter 3 Nelson outlines the 30-year struggle to expand the park. Changes in the field of ecology, with new concepts in biodiversity, landscape ecology, conservation biology, and population viability, made it possible to better understand, plan, and manage wildland ecosystems. On-the-ground research involving radio-telemetry showed that Grizzly Bears (*Ursos arctos*), Caribou (*Rangifer tarandus*), and Dall's Sheep (*Ovis dalli*) were all undertaking seasonal movements that took them well beyond the boundaries of the small reserve. New park concepts of ecological integrity, the idea of "inhabited wilderness", and a shift from top-down to co-operative management with First Nations were also fundamental to the expansion of the reserve in 2009 to include most of the Nahanni River watershed.

In Part II ("Why and How the Natural Qualities of the Nahanni were Conserved in the Past"), Nelson goes back in time to explore the impacts of the 19th-century

fur trade on the First Nations and wildlife of the Nahanni region, setting it within the context of broader activities in northwestern North America. The First Nations of the Nahanni region were already linked to an extensive native trade network through the regions we know as Yukon, British Columbia, and Washington, as well as to the Russian fur traders in present-day Alaska. While the local First Nations did not seem to be as involved or interested in trading furs as those in some other areas, the competition among incoming traders did reduce the number of fur-bearers, and local game populations (e.g., Moose [*Alces americanus*]) that were previously relied on by indigenous people for food. Nelson's reliance on scholarly research material led him to extrapolate local First Nations' historical use of resources from those of peoples in the Yellowstone area and Alaska; I would have thought there would have been more relevant local traditional knowledge that he could have referenced. By the early 1900s, with the fur trade gone, there were sporadic searches for gold in the Nahanni Valley. By the 1930s individual prospectors were replaced by companies and corporations more capable of financing the search for, and development of, mineral resources. There was even a proposal to build a dam at Virginia Falls to provide power for mining companies. Through the roughly 200 years of fur trading and mining, the difficult terrain, harsh climate, uneven distribution of resources, conflict and competition with rivals, and changes in markets or economic and political conditions, inadvertently conserved the ecological integrity of the Nahanni.

Nelson looks to future challenges and opportunities in Part III ("The Struggle Continues"). He lumps the challenges into two groups: those that mostly affect the natural diversity and ecological integrity of the watershed, and those that mainly relate to the indigenous people in the protected area. Foremost in the first group is a zinc mine on Prairie Creek, a tributary to the Nahanni, that is surrounded by park reserve. It was approved in 2011 over considerable shortcomings in the environmental assessment and stated opposition by environmental groups and First Nations. If developed the mine could significantly affect the aquatic ecosystem. On the opportunity spectrum is the possibility of the park becoming a centre for indigenous culture and learning, youth education, and Traditional Ecological Knowledge research. In the final chapter, Nelson wraps up his case study by looking at the significance of co-operation in research, planning and management of protected areas by government, non-governmental organizations, and indigenous people with examples from around the world.

The Nahanni River is not the longest (only about 500 km) nor the hardest river to paddle, but it slices through the heart of a region that abounds in grandeur and natural diversity, and this book will help the reader appreciate it all the more.

CYNDI M. SMITH
Canmore, AB, Canada

Coexistence: The Ecology and Evolution of Tropical Biodiversity

By Jan Sapp. 2016. Oxford University Press. 275 pages, 49.95 USD, Cloth.

Coexistence: The Ecology and Evolution of Tropical Biodiversity is a fascinating chronology and reconstruction of the history of the science of tropical ecology in the Western Hemisphere. The book is framed as a history of the Smithsonian Tropical Research Island (STRI) on Barro Colorado Island in the Lago Gatun of the Panama Canal, but it also provides a broad history of the theories, debates, and research surrounding the evolution and maturing of tropical ecology. The author skillfully weaves in the development and evolution of theories related to tropical diversity (forests and corals) and why so many species can coexist in tropical ecosystems. At its essence, the debate is about how 50% of the global plant and animal species diversity can coexist on only 2% of the planet's area. At one level, the book would seem narrowly focussed on essentially how scientists attempted to explain how many species could occupy the same habitat in tropical ecosystems (both tropical forests and marine coral reefs). But at another level the book is a fascinating chronology of the development and maturing of science through the proposal and subsequent refuting of many competing hypotheses. The establishment and development of the STRI is used as a template for explaining the much broader evolution of tropical forest and marine ecology.

While both scientists and lay readers may now accept tropical ecology as a given and accepted sphere of ecology, this was not always the case. At one time it was assumed that principles of temperate forest ecology, where the earliest scientific strides had been made, would directly apply to the tropics. It is interesting how much of the early field of ecology was based upon research in temperate regions, and how strongly that influenced initial theories of tropical ecology.

The initial tropical research station in the isolated Panamanian rainforest which became the STRI was the first one established for the express purpose of studying tropical natural history rather than applied agricultural research. Major marine research on both Atlantic and Pacific marine coral ecosystems also evolved out of this research initiative. This provided the unique opportunity to study fish community structure and ecology in two totally different marine ecosystems, separated by major geologic events in the past and yet only 65 km apart.

A dizzying and competing sequence of theories has been developed to explain tropical biodiversity. The author has done a masterful job of explaining the scientific complexities of the various theories of tropical ecology and evolution that led to the establishment of the research station, and how those theories and concepts evolved through time in a manner true to the science and yet understandable and interesting to the lay person. Like a skilful mystery writer, the author leads us from one potential hypothesis to another, building

up the basis for the theory, the subsequent research to prove or disprove the hypothesis, the scientific debates and arguments, and the inevitable refinement and alternative hypothesis that took its place, leading to the book's final analysis and conclusions.

The author has an impressive grasp of scientific literature from a diverse range of fields and portrays an amazing understanding of scientific principles and processes. As one example, his grasp of biological, evolutionary, and geological history was evident in the succinct summary of processes leading to the mass extinction of marine species that resulted from the geological closure of the seaway and the creation of the Panamanian isthmus.

While the title may suggest a book with a rather limited target audience, it is a fascinating and very compelling story of interest to scientists and lay readers alike. The author obviously did a great deal of meticulous research, scrutinizing scientific publications, letters, research notes, chronicled archives of the research institute, popular articles, and personal interviews. These are skillfully and seamlessly woven into a fascinating chronology of the parallel evolution of the Barro Colorado Island field station and tropical ecology as a scientific field. In its 275 pages, 50 devoted to scientific references. Almost every fact noted has an accompanying reference. I found myself repeatedly flipping back to the reference section simply out of curiosity to see what the source could be of yet another interesting nugget of tropical science history.

Some of the early history is especially fascinating, detailing the vision, boldness, and courage that brought the concept of the Barro Colorado reserve to life. There are fascinating stories of the early unique research scientists and their often-fractious relationships. The stories are accompanied by grainy black and white photos that add to the historical perspective. The impacts of history and politics on science, sometimes in totally unforeseen ways, provided interesting insights. These included the role of construction of the Panama Canal on the stimulation of interest in tropical research, and the effects of the American invasion of Panama. The book provides fascinating insights into the canal's history, such as the very serious proposal to use nuclear devices to create a sea-level canal rather than a series of freshwater locks, and the kidnapping of marine research scientists during the Panamanian invasion.

There are many interesting elements to the gradual maturing of tropical ecology as a scientific discipline, which the author carefully researched and clearly and succinctly described. Tropical research innovated and initiated the use of canopy towers to study all manner of scientific questions without disturbing the flora or fauna, eventually leading to a global network of tropical canopy towers. Another initiative was the develop-

ment of large, permanent study plots which, despite all the debate about the source and status of tropical diversity, no one had previously thought to establish. This eventually led to the creation of a global, interlinked network, which is proving useful to current research on the effects of climate change.

As well as detailing the development and evolution of the research station, and almost as an aside, the book objectively and without comment describes the parallel evolution of growing gender parity on the island over the decades. In the early years women were not permitted on the island, for fear of proving a distraction, and children and families were discouraged. Eventually female scientists came into their own, initially assisting with their husbands' research, often as unpaid research assistants, and later as fully independent and autonomous research scientists.

Author Jan Sapp is a Professor of Biology and History at Toronto's York University, but, not surprisingly, this book on tropical ecology has few references to Canada. References I noted related to the Welland Canal, which allowed Sea Lamprey (*Petromyzon marinus*) into the upper Great Lakes, an example of ecological implications with parallels to what was proposed in Panama, and a reference to a McGill biologist's reviewing of Stephen Hubbell's book on neutral theory.

Coexistence provides a fascinating and comprehensive overview of the evolution of tropical forest and marine ecology and their rapidly expanding research sphere. For the most part it is tightly researched and

edited, and almost no distracting typographic or spelling errors were noted. However, it does suffer from a few minor inconveniences at the micro scale. The need to convert between Imperial and metric measures was a minor annoyance. The first hint that the book was losing its tight editorial focus came in Chapter 9, when three references in as many pages were made to the portending canal treaties that would terminate the Canal Zone in 1979. A few other duplicate references to historical facts were scattered throughout the text, where notable facts appeared to have been collected and inadvertently inserted twice. Unfortunately, the same level of detail that went into the research and writing did not go into making optimal use of the interesting and informative historical photos. While these black and white photos helped the reader to envision the historical period, their placement and use was at times distracting and almost haphazard. The figure was often not placed with the first reference to the subject matter, and often the content of the photo and the textual reference were only tangentially related.

This is a meaty book that cannot be read quickly but must be contemplated and absorbed. Although it is focussed primarily on tropical ecology, it is also a fascinating chronology of a detailed and skillfully researched scientific history that both scientists and lay readers can learn from and enjoy.

TED ARMSTRONG

Thunder Bay, ON, Canada

The Eye of the Sandpiper: Stories from the Living World

By Brandon Keim. 2017. Cornell University Press. 266 pages, 23.98 CAD, Paper.

This book is a thoughtful journey exploring the natural world, the ongoing research into it, while questioning our relationship with it. Based on the cover and title I expected this to be a book full of shorebird research, and so was surprised to read about a variety of life from birds to fish. Keim does a wonderful job choosing stories that capture the audiences' interest and leaves us wanting to know more.

These short stories are organized into thematic sections including: Dynamics, Inner Lives, Intersections, and Ethics.

The first theme draws on evolution and ecological dynamics of the natural world. In this section we read about Cane Toads (*Rhinella marina*), chickadees, Monarch Butterflies (*Danaus plexippus*), and more. He explored stories about the deep sea, challenged how we think about Sea Lamprey (*Petromyzon marinus*), and reminded us to listen, literally, to the natural world.

The second theme expands on the inner lives of animals. Keim draws on research that many may consider anthropomorphic topics, such as empathy, self-awareness, language, mental-time travel, and emotions.

It was fascinating to read some of the research being conducted on species we may see around us daily, such as honeybees, mice, rats, and birds.

The third theme, Intersections, is full of stories about people who are applying our knowledge to the world. These stories provide the book with views of hope through the passion people have and the direct changes they can make.

The final theme, Ethics, centres on humanity's role in the future of nature. Human activities have influenced the earth so much that Keim delves into the idea of the Anthropocene throughout this chapter. Topics raised include the ideas of wildness and wilderness, bringing back extinct species, and non-native species.

Chapters were very well written, but I often found myself wishing that they were not so short. Some controversial topics, such as the removal of invasive species such as Mute Swans (*Cygnus olor*) or feral cats, were presented with points of view from both sides. Environmental problems can often be a depressing topic; however, Keim's stories approach them in a way that is interesting and instils a sense of hope. I appre-

ciated that this book was not only well researched and thought provoking, but Keim's curiosity for the natural world was contagious.

Books like this play an important role as they help communicate research to the public. The primary audience of this book is likely already those who read science articles; however, many of the stories and interesting facts could reach a broader audience interested in the natural world. The wide variety of subjects allowed me to learn about species and topics I may not have sought out otherwise.

Throughout this book I found an overarching call to become aware of my surroundings and to learn to act in ways that nourish the life around me, both human and non-human. Perhaps if we pay more attention and further appreciate and respect the non-human world, we will care more about the place we call home and those we share it with.

TIANNA BURKE

Parry Sound, ON, Canada

NEW TITLES

Prepared by Barry Cottam

Please note: Only books marked † Available for review or * Assigned have been received from publishers. All other titles are listed as books of potential interest to subscribers. Please send notice of new books – or copies for review – to the Book Review Editor.

†Available for review *Assigned

Currency Codes – CAD Canadian Dollars, USD US Dollars, EUR Euros, AUD Australian Dollars, GBP British Pound.

BOTANY

Diversity and Phylogeny of the Monocotyledons: Contributions from Monocots V. Memoirs of The New York Botanical Garden Volume 118. Edited by Lisa Campbell, Jerrold I. Davis, Alan W. Meerow, Robert F. C. Naezi, Dennis W. Stevenson, and W. Wayt Thomas. 2017. New York Botanical Garden Press. 172 pages, 89.99 USD, Cloth.

Plant Life: A Brief History. By Frederick B. Essig. 2015. Oxford University Press. 280 pages, 74.00 CAD, Cloth. Also available as an E-book.

Grasses of the Great Plains. By James Stubbendieck, Stephan L. Hatch, and Cheryl D. Dunn. 2017. Texas A&M University Press. 736 pages, 50.00 USD, Cloth.

Plants of the World: An Illustrated Encyclopedia of Vascular Plant Families. By Maarten J. M. Christenhusz, Michael F. Fay, and Mark W. Chase. 2017. Royal Botanic Gardens, Kew University of Chicago Press. 816 pages and 3000 colour plates, 95.00 USD, Cloth or E-book.

***Catalogue of the Vascular Plants of New York State. Memoirs of the Torrey Botanical Society Volume 27.** By David Werier. 2017. Torrey Botanical Society. 543 pages, 35.00 CAD, Cloth. Also available as an E-book.

Fortress Plant: How to Survive When Everything Wants to Eat You. By Dale Walters. 2017. Oxford University Press. 320 pages, 29.95 CAD, Cloth. Also available as an E-book.

The Cabaret of Plants: Forty Thousand Years of Plant Life and the Human Imagination. By Richard Mabey. 2017. W.W. Norton. 384 pages, 17.95 USD, Paper.

†**Carnivorous Plants: Physiology, Ecology, and Evolution.** Edited by Aaron Ellison and Lubomir Adamec. 2018. 544 pages, 125.00 CAD, Cloth. Also available as an E-book.

Plants That Kill: A Natural History of the World's Most Poisonous Plants. By Elizabeth A. Dauncey and Sonny Larsson. 2018. Princeton University Press. 224 pages, 29.95 USD, Cloth.

The Long, Long Life of Trees. By Fiona Stafford. 2017. Yale University Press. 296 pages, 18.00 USD, Paper.

***Identification of Trees and Shrubs in Winter Using Buds and Twigs.** By Bernd Schulz. 2018. Royal Botanic Gardens, Kew; distributed by University of Chicago Press. 368 pages, 45.00 GBP, 80.00 USD, Cloth.

***Flora of Florida, Volume IV: Dicotyledons, Combretaceae through Amaranthaceae.** By Richard P. Wunderlin, Bruce E. Hansen, and Alan R. Franck. 2017. University Press of Florida. 400 pages, 69.95 USD, Cloth.

ENTOMOLOGY

The Moths of America North of Mexico, Fascicle 9.5: *Pelochrista* Lederer of the Contiguous United States and Canada (Lepidoptera: Tortricidae: Eucosmini). By Donald J. Wright and Todd M. Gilligan. 2017. The Wedge Entomological Research Foundation. 376 pages, 168 species accounts, 48 plates with 720 colour photos, and 70 plates with 945 black and white line drawings, 90.00 USD, Cloth.

***The Green Menace: Emerald Ash Borer and the Invasive Species Problem.** By Jordan D. Marché II. 2017. Oxford University Press. 320 pages, 69.95 USD, Cloth.

Bees: An Identification and Native Plant Forage Guide. By Heather Holm. 2017. Pollination Press LLC. 224 pages, 29.95 CAD/USD, Paper.

Listening to the Bees. By Mark Winston and Renée Sarojini Saklikar. 2018. Harbour Publishing. 192 pages, 24.95 CAD/USD, Cloth.

Ant-Plant Interactions: Impacts of Humans on Terrestrial Ecosystems. Edited by Paulo S. Oliveira and Suzanne Koptur. 2017. Cambridge University Press. 452 pages, 84.99 USD, Cloth, 68.00 USD, E-book.

Garden Insects of North America: The Ultimate Guide to Backyard Bugs, Second Edition. By Whitney Cranshaw and David Shetlar. 2017. Princeton University Press. 704 pages and 3300 colour photos, 35.00 USD, 27.95 GBP, Paper.

A Swift Guide to Butterflies of Mexico and Central America, Second Edition. By Jeffrey Glassberg. 2018. Princeton University Press. 304 pages and 3250 colour photos and maps, 39.95 CAD, Paper. Also available as an E-book.

Hidden Kingdom: The Insect Life of Costa Rica. By Piotr Naskrecki. 2017. Comstock Publishing Associates/Zona Tropical Publications. 216 pages and 900 photos and illustrations, 34.95 USD, Paper.

ORNITHOLOGY

Bird Migration Across the Himalayas: Wetland Functioning Amidst Mountains and Glaciers. Edited by Herbert H. T. Prins and Tsewang Namgail. Foreword by The Dalai Lama. 2017. Cambridge Oxford University Press. 458 pages, 75.00 GBP, Cloth.

The Sensory Ecology of Birds. By Graham R. Martin. 2017. Oxford University Press. 320 pages, 95.00 CAD, Cloth. Also available through Oxford Scholarship Online.

Gulls of the World: A Photographic Guide. By Klaus Malling Olsen. 2018. Princeton University Press. 488 pages and 600 photos, 45.00 USD, Cloth.

At Sea with the Marine Birds of the Raincoast. By Caroline Fox. 2016. Rocky Mountain Books. 224 pages, 40.00 CAD, Cloth, 12.99 CAD, E-book.

Far from Land: The Mysterious Lives of Seabirds. By Michael Brooke. Illustrations by Bruce Pearson. 2018. Princeton University Press. 272 pages, 29.95 USD, Cloth.

The Seabird's Cry: The Lives and Loves of Puffins, Gannets and Other Ocean Voyagers. By Adam Nicolson. Illustrations by Kate Boxer. 2017. William Collins (Harper Collins imprint). 228 pages, 16.99 GBP, Cloth, 9.99 GBP, Paper or E-book.

Project Puffin: The Improbable Quest to Bring a Beloved Seabird Back to Egg Rock. By Stephen W. Kress and Derrick Z. Jackson. 2015 (Cloth), 2017 (Paper). Yale University Press. 365 pages, 30.00 USD, Cloth, 20.00 USD, Paper.

Seabirds Beyond the Mountain Crest: The History, Natural History and Conservation of Hutton's Shearwater. By

Richard Cuthbert. 2017. Otago University Press. 220 pages, 45.00 NZD, Paper.

†**The Birds at My Table: Why We Feed Wild Birds and Why It Matters.** By Darryl Jones. 2018. Comstock Publishing Associates/Cornell University Press. 352 pages, 19.95 USD, Paper.

National Geographic Field Guide to the Birds of North America, Seventh Edition. By Jon L. Dunn and Jonathan Alderfer. Illustrations by Paul Lehman. 2017. National Geographic Society. 592 pages, 29.99 USD, Paper.

Birds of Nicaragua: A Field Guide. By Liliana Chavarria-Durieux. 2018. Cornell University Press. 346 pages, 29.95 USD, Paper.

Woodpecker. By Gerard Gorman. 2017. Reaktion Books. 224 pages, 19.95 USD, Paper.

The Enigma of the Owl: An Illustrated Natural History. By Mike Unwin and David Tipling. Foreword by Tony Angell. 2017. Yale University Press. 288 pages and 200 colour illustrations, 40.00 USD, Cloth.

One More Warbler: A Life with Birds. By Victor Emanuel with S. Kirk Walsh. 2017. University of Texas Press. 295 pages, 29.95 USD, Cloth.

The Meaning of Birds. By Simon Barnes. 2018. Pegasus Books. 208 pages, 26.95 USD, Cloth. Also available as an E-book.

Those of the Gray Wind. The Sand Hill Cranes, New Edition. By Paul A. Johnsgard. With a new preface and afterword by the author. 2017. University of Nebraska Press. 174 pages, 14.95 USD, Paper.

Vanished and Vanishing Parrots: Profiling Extinct and Endangered Species. By Joseph Forshaw. Illustrations by Frank Knight. 2017. Comstock Publishing Associates. 344 pages, 95.00 USD, Cloth. Also available as an E-book.

ZOOLOGY

Are We Smart Enough to Know How Smart Animals Are? By Frans de Waal. 2017. W. W. Norton. 352 pages, 27.95 USD, Cloth, 16.95 USD, Paper.

Carnivore Minds: Who These Fearsome Animals Really Are. By G. A. Bradshaw. 2017. Yale University Press. 360 pages, 35.00 USD, Cloth.

Following Fifi: My Adventures Among Wild Chimpanzees: Lessons from our Closest Relatives. By John Crocker. Foreword by Jane Goodall. 2017. Pegasus Books. 272 pages, 27.95 USD, Cloth. Also available as an E-book.

†**Evolutionary Ecology of Marine Invertebrate Larvae.** Edited by Tyler Carrier, Adam Reitzel, and Andreas Heyland. 2018. Oxford University Press. 368 pages, 105.00 CAD, Cloth, 55.00 CAD, Paper. Also available as an E-book.

Essential Fish Biology: Diversity, Structure, and Function. By Derek Burton and Margaret Burton. 2017. Oxford Univer-

sity Press. 416 pages, 105.00 CAD, Cloth, 55.00 CAD, Paper. Also available as an E-book.

Immersion: The Science and Mystery of Freshwater Muscels. By Abbie Gascho Landis. 2017. Island Press. 256 pages, 30.00 USD, Cloth or E-book.

Marine Ecosystem-Based Management in Practice: Different Pathways, Common Lessons. By Julia Wondolleck and Steven Yaffee. 2017. Island Press. 288 pages, 70.00 USD, Cloth, 35.00 USD, Paper or E-book.

***Marine Fishes of Arctic Canada.** Edited by Brian W. Coad and James D. Reist. 2017. University of Toronto Press. 632 pages and 200 illustrations, 74.96 CAD, Cloth or E-book.

The Marine World: A Natural History of Ocean Life. By Frances Dipper. Foreword by Mark Carwardine. 2017. Comstock Publishing Associates. 544 pages, 59.95 USD, Cloth.

Global Atlas of Marine Fisheries: A Critical Appraisal of Catches and Ecosystem Impacts. Edited by Daniel Pauly and Dirk Zeller. 2016. Island Press. 520 pages and 612 illustrations, 160.00 USD, Cloth, 80.00 USD, Paper, 59.99 USD, E-book.

Whales: Their Biology and Behavior. By Phillip Hammond, Sonja Heinrich, Sascha Hooker, and Peter Tyack. 2017. Cornell University Press. Comstock Publishing Associates. 144 pages, 19.95 USD, Paper.

Wildlife of the Arctic. By Richard Sale and Per Michelsen. 2018. Princeton University Press. 304 pages and 800 photos, 19.95 USD, Paper.

On the Wing: Insects, Pterosaurs, Birds, Bats and the Evolution of Animal Flight. By David E. Alexander. 2015. Oxford University Press. 224 pages, 31.95 CAD, Cloth.

***Great Plains Bison.** Discover the Great Plains Series. By Dan O'Brien. 2017. University of Nebraska Press. Bison Books. 144 pages, 14.95 USD, Paper.

Handbook of the Mammals of the World, Volume 7. Rodents II. By Don E. Wilson, Thomas E. Lacher, Jr., and Russell A. Mittermeier. Illustrations by Toni Llobet. 2017. Lynx Edicions in association with Conservation International and IUCN. 1008 pages, 160.00 EUR, Cloth.

Biology and Conservation of Musteloids. Edited by David W. Macdonald, Chris Newman, and Lauren A. Harrington. 2018. Oxford University Press. 672 pages, 125.00 CAD, Cloth, 60.00 CAD, Paper. Also available as an E-book.

Chimpanzees and Human Evolution. Edited by Martin N. Muller, Richard W. Wrangham, and David R. Pilbeam. 2017. Belknap Press Harvard University Press. 794 pages, 55.00 USD, Cloth.

Mimicry, Crypsis, Masquerade and other Adaptive Resemblances. By Donald L. J. Quicke. 2017. Wiley-Blackwell. 576 pages, 114.00 CAD, Cloth, 91.99 CAD, E-book.

Biochemical Adaptation: Response to Environmental Challenges from Life's Origins to the Anthropocene. By George N. Somero, Brent L. Lockwood, and Lars Tomanek.

2017. Sinauer Associates, an imprint of Oxford University Press. 572 pages, 112.95 CAD, Cloth. Also available as an E-book.

Venom: The Secrets of Nature's Deadliest Weapon. By Ronald Jenner and Eivind Undheim. 2017. CSIRO Publishing. 208 pages, 29.95 AUD, Paper.

Where the Animals Go: Tracking Wildlife with Technology in 50 Maps and Graphics. By James Cheshire and Oliver Uberti. 2017. W. W. Norton. 192 pages, 39.95 USD, Cloth.

The Pipestone Wolves: The Rise and Fall of a Wolf Family. By Günther Bloch. Photography by John E. Marriott. Foreword by Mike Gibeau. 2016. Rocky Mountain Books. 224 pages, 40.00 CAD, Cloth.

Leaving the Wild: The Unnatural History of Dogs, Cats, Cows, and Horses. By Gavin Ehringer. 2017. Pegasus Books. 336 pages, 27.95 USD, Cloth. Also available as an E-book.

OTHER

Sustaining Lake Superior: An Extraordinary Lake in a Changing World. By Nancy Langston. 2017. Yale University Press. 312 pages, 35.00 USD, Cloth.

Journeys Through Paradise: Pioneering Naturalists in the Southeast. By Gail Fishman. 2017. University Press of Florida. 328 pages, 24.95 USD, Paper.

Heart Waters: Sources of the Bow River. By Kevin Van Tighem. Photography by Brian Van Tighem. 2015. Rocky Mountain Books. 240 pages, 40.00 CAD, Cloth.

***Searching for Mary Schäffer.** Mountain Cairns: A Series on the History and Culture of the Canadian Rocky Mountains. By Colleen Skidmore. 2017. University of Alberta Press. 376 pages, 34.95 CAD, Paper, 27.99 CAD, E-book.

Orange Omelettes & Dusky Wanderers: Studies and Travels in Seychelles Over Four Decades. By Chris J. Feare. 2017. Calusa Bay Publications. 342 pages, 13.99 GBP, Paper.

***Islands of Grass.** By Trevor Herriot. Photography by Branimir Gjetvaj. 2017. Coteau Books. 224 pages, 39.95 CAD USD, Cloth.

Invasion Dynamics. By Cang Hui and David M. Richardson. 2017. Oxford University Press. 336 pages, 115.00 CAD, Cloth, 59.95 CAD, Paper. Also available as an E-book and through Oxford Scholarship Online.

Firestorm: How Wildfire Will Shape Our Future. By Edward Struzik. 2017. Island Press. 272 pages, 30.00 USD, Cloth or E-book.

Costly Fix: Power, Politics, and Nature in the Tar Sands. By Ian Urquhart. 2018. University of Toronto Press. 384 pages, 95.00 CAD, Cloth, 39.95 CAD, Paper, 31.95 CAD, E-book.

Half-Earth: Our Planet's Fight for Life. By Edward O. Wilson. 2017. Liveright Publishing Corporation. 272 pages, 25.95 USD, Cloth, 16.95 USD, Paper.

The Archipelago of Hope: Wisdom and Resilience from the Edge of Climate Change. By Gleb Raygorodetsky. 2017. Pegasus Books. 336 pages, 28.95 USD, Cloth. Also available as an E-book.

Nature's Allies: Eight Conservationists Who Changed Our World. By Larry Neilsen. 2017. Island Press. 272 pages, 21.00 USD, Paper.

What Should a Clever Moose Eat? Natural History, Ecology, and the North Woods. By John Pastor. Foreword by Bernd Heinrich. 2016. Island Press. 336 pages, 30.00 USD, Cloth or E-book.

Essentials of Soil Science: Soil Formation, Functions, Use and Classification (World Reference Base, WRB). By Winfried Blum, Peter Schad, and Stephen Nortcliff. 2017. CSIRO Publishing. 176 pages, 59.95 AUD, Paper.

Big Pacific: An Incredible Journey of Exploration and Revelation. Edited by Rebecca Tansley. 2017. CSIRO Publishing. 240 pages, 49.95 AUD, Cloth.

Enhancing Science Impact: Bridging Research, Policy and Practice for Sustainability. By Peat Leith, Kevin O'Toole, Marcus Haward, and Brian Coffey. 2017. CSIRO Publishing. 216 pages, 59.95 AUD, Paper. Also available as an E-book.

Inheritors of the Earth: How Nature is Thriving in an Age of Extinction. By Chris D. Thomas. 2017. Allen Lane. 320 pages, 20.00 GBP, Cloth.

Wildlife, Land, and People: A Century of Change in Prairie Canada. By Donald G. Wetherell. 2016. McGill-Queen's University Press. 640 pages, 49.95 CAD, Cloth. Also available as an E-book.

The Biology of Ponds and Lakes, Third Edition. By Christer Brönmark and Lars-Anders Hansson. 2017. Oxford University Press, Biology of Habitats Series. 368 pages, 95.00 CAD, Cloth, 45.95 CAD, Paper. Also available as an E-book.

***Exploring the Limestone Barrens of Newfoundland and Labrador.** By Burzynski, M. H. Mann, and A. Marceau. 2016. Gros Morne Co-operating Association. 364 pages, 26.95 CAD, Paper.

†The Inner Life of Animals: Love, Grief, and Compassion — Surprising Observations of a Hidden World. By Peter Wohlleben. Translated by Jane Billinghurst. 2017. Greystone Books. 272 pages, 29.95 CAD, Cloth.

Wild Sex: The Science Behind Mating in the Animal Kingdom. By Carin Bondar. 2016. Pegasus Books. 400 pages, 27.95 USD, Cloth. Also available as an E-book.

Swamp: Nature and Culture. By Anthony Wilson. 2017. Reaktion Books. 248 pages, 24.95 USD, Paper.

Not So Different: Finding Human Nature in Animals. By Nathan H. Lents. 2017. Columbia University Press. 368 pages, 26.00 USD, Paper. Cloth and E-book published in 2016.

The Nature Fix: Why Nature Makes Us Happier, Healthier, and More Creative. By Florence Williams. 2017. W. W. Norton. 272 pages, 26.95 USD, Cloth, 15.95 USD, Paper.

Our Vanishing Glaciers: The Snows of Yesteryear and the Future Climate of the Mountain West. By Robert William Sandford. 2017. Rocky Mountain Books. 224 pages, 40.00 CAD, Cloth.

Our Place: Changing the Nature of Alberta. By Kevin Van Tighem. 2017. Rocky Mountain Books. 376 pages, 25.00 CAD, Paper, 9.99 CAD, E-book.

The Evolution Underground: Burrows, Bunkers, and the Marvelous Subterranean World Beneath our Feet. By Anthony J. Martin. 2017. Pegasus Books. 400 pages, 28.95 USD, Cloth. Also available as an E-book.

The Face of Nature: An Environmental History of the Otago Peninsula. By Jonathan West. 2017. Otago University Press. 388 pages, 49.95 NZD, Paper.

Editors' Report for Volume 130 (2016)

Mailing dates for the four issues in volume 130 are as follows: 17 June 2016; 30 September 2016; 16 December 2016; 21 April 2017. Summaries of the distribution of memberships in the Ottawa Field-Naturalists' Club, who all receive access to *The Canadian Field-Naturalist*, and subscribers to *The Canadian Field-Naturalist* for 2016 are provided in Table 1, along with comparison numbers for volume 129. Institutional subscribers potentially represent many thousands of users. The number of Articles and Notes in volume 130 is summarized in Table 2 by topic. Totals for book reviews and new titles are given in Table 3, and the distribution of content by page totals per issue is provided in Table 4. Sixty-nine manuscripts were submitted to *The Canadian Field-Naturalist* in 2016: only 25 of these were submitted by email with all those after July submitted using the Online Journal System. Of the 69 submissions, 57 (82.6%) were accepted for publication and either published or undergoing further revision and review, nine were not accepted upon initial submission or review, two were not accepted upon revision, and one was withdrawn. A total of 30 Articles, 20 Notes, and two Tributes were published in 2016.

Dwayne Lepitzki began the transition to Editor-in-Chief from Carolyn Callaghan with issue 2. Amanda Martin, Assistant Editor, edited content, proofread galleys, compiled the "Upcoming Meetings and Workshops" section of the News and Comments, and sent and received author order and transfer of copyright forms. Sandra Garland and, beginning with issue 4, John Wilmshurst proofed and copy edited manuscripts. Wendy Cotie typeset galleys, provided corrections for page proofs, and created pdfs. Roy John and, beginning with issue 3, Barry Cottam requested books for review, selected reviewers, edited submitted reviews, and prepared the new titles listings. Ken Young assumed the duties for managing subscriptions and page charge invoices from Eleanor Zurbrigg with issue 2. William Halliday, Journal Manager and Webmaster, provided digital content to subscribers, posted tables of contents, abstracts, and pdfs on *The Canadian Field-Naturalist* website, and prepared the Index. Our Associate Editors managed manuscripts, provided reviews and recommendations, and guided authors through the revisions process. The Publication Committee, chaired by Jeff Saarela and consisting of Annie Bélair, Dan Brunton, Carolyn Callaghan, Paul Catling, Barry Cottam, Tony Gaston (resigned late in 2016), William Halliday, Diane Kitching, Dwayne Lepitzki, Amanda Martin, Karen McLachlan Hamilton, Frank Pope, and David Seburn effectively guided the operation of the journal. We are indebted to our very dedicated team.

TABLE 1. The 2016 (2015) circulation of *The Canadian Field-Naturalist*. Compiled by Ken Young from the subscription list for 130(4).

Subscriber Type	Canada		USA		Other		Total	
OFNC Members	58	(61)	3	(3)	1	(1)	62	(65)
Subscriptions:								
Individual	21	(12)	6	(6)	1	(0)	28	(18)
Institutional	84	(107)	116	(158)	13	(19)	213	(284)
Total	163	(180)	125	(167)	15	(20)	303	(367)

TABLE 2. Number of research articles and notes published in *The Canadian Field-Naturalist*, Volume 130 (Volume 129), by major field of study.

Subject	Articles	Notes	Total
Mammals	9 (7)	10 (6)	19 (13)
Birds	4 (7)	5 (5)	9 (12)
Amphibians and Reptiles	4 (2)	0 (3)	4 (5)
Fishes	4 (4)	2 (2)	6 (6)
Plants	4 (5)	1 (2)	5 (7)
Insects	2 (1)	0 (0)	2 (1)
Non-insect Invertebrates	3 (2)	2 (1)	5 (3)
Total	30 (28)	20 (19)	50 (47)

TABLE 3. Number of reviews and new titles published in the Book Review section of *The Canadian Field-Naturalist*, Volume 130 (Volume 129), by topic.

	Reviews	New Titles
Zoology	10 (18)	45 (26)
Botany	3 (3)	16 (2)
Miscellaneous	9 (14)	32 (19)
Total	22 (35)	93 (47)

The following Associate Editors managed, assessed, and reviewed manuscripts published in volume 130: P. M. Catling, Agriculture and Agri-Food Canada, Ottawa ON (4 manuscripts); F. Chapleau, University of Ottawa, Ottawa ON (4); F. R. Cook, Emeritus Research Associate, Canadian Museum of Nature, Ottawa ON (5); J. Foote, Algoma University, Sault Ste. Marie ON (4); G. Forbes, University of New Brunswick, Fredericton NB (1); A. J. Gaston, Environment Canada (emeritus), Ottawa ON (4); T. Jung, Yukon Government, Whitehorse YT (3); D. F. McAlpine, New Brunswick Museum, Saint John NB (5); G. Mowat, government of British Columbia, Nelson BC (3); D. W. Nagorsen, Mammalia Biological Consulting, Victoria BC (7); M. Obbard, Ontario Ministry of Natural Resources and Forestry, Peterborough ON (3); C. Renaud, Canadian Museum of Nature, Ottawa ON (2); J. M. Saarela, Canadian Museum of Nature, Ottawa ON (3); J. Skevington, Agriculture and Agri-Food Canada, Ottawa ON (2).

The following referees reviewed manuscripts published in volume 130 (number of manuscripts reviewed -1 in parenthe-

TABLE 4. Number of pages per section published in *The Canadian Field-Naturalist*, Volume 130 (Volume 129), by issue.

	Issue				Total
	1	2	3	4	
Editorials/Editor's Report	0 (0)	3 (3)	0 (0)	0 (0)	3 (3)
Articles	63 (59)	73 (66)	43 (44)	59 (72)	238 (241)
Notes	18 (30)	14 (16)	14 (30)	21 (14)	67 (90)
Tributes	0 (7)	0 (0)	0 (0)	18 (0)	18 (7)
Book Reviews*	8 (15)	4 (10)	9 (14)	11 (4)	32 (43)
News and Comment	1 (3)	2 (9)	3 (2)	4 (2)	10 (16)
Reports†	0 (0)	4 (0)	15 (13)	0 (5)	19 (18)
Erratum	0 (0)	0 (0)	0 (1)	0 (0)	0 (1)
Index	– (–)	– (–)	– (–)	7 (7)	7 (7)
Total	90 (114)	100 (104)	84 (104)	120 (104)	394 (426)

*Includes reviews and new titles.
†Includes Annual Business Meeting Minutes, Annual Committee Reports, Financial Statements, Awards.

ses); Ray Alisauskas, Environment and Climate Change Canada; Mike Anderson, Ducks Unlimited Canada (emeritus); Carl D. Anthony, John Carroll University; Robin Baird, Olympia WA; Peter Ball, University of Toronto; Shannon Barber-Meyer, US Geological Survey; Erin Bayne, University of Alberta; John Benson, University of Nebraska—Lincoln; Jennifer Bigman, Simon Fraser University; Anne Bjorkman, German Centre for Integrative Biodiversity Research, Leipzig; Gabriel Blouin-Demers, University of Ottawa; Jeff Bowman, Ontario Ministry of Natural Resources and Forestry; Dan Brunton, Ottawa ON (2); Joseph Bump, Michigan Technological University; Jonathan Choquette, Guelph ON; Jonathan Cormier, New Brunswick Department of Natural Resources; Aurélie Cosandey Godin, Dalhousie University; Hugo Cota, University of Saskatchewan; Brenda Dale, Environment and Climate Change Canada; Christina Davey, Trent University; Dick Dekker, Edmonton AB; A. W. Diamond, University of New Brunswick; Mark Edwards, Royal Alberta Museum; Mark Elbroch, Panthera NY; Marco Festa-Bianchet, Université de Sherbrooke; Graham Forbes, University of New Brunswick; Bruce Ford, University of Manitoba; Robert Forsyth, Kamloops BC; Jochen Gerber, The Field Museum; John Gilhen, Nova Scotia Museum of Natural History (2); Scott Gillingwater, Upper Thames River Conservation Authority; Emily Gonzales, Parks Canada; Karen Graham, Foothills Research Institute; Patrick Gregory, University of Victoria; Samuel Haché, Canadian Wildlife Service; Gavin Hawke, Royal British Columbia Museum; Douglas Heard, University of Northern British Columbia; Raymond Hutchinson, Ottawa ON; Louis Imbeau, Université du Québec en Abitibi-Témiscamingue; James Irvine, Fisheries and Oceans Canada; S. J. Iverson, Canadian Wildlife Service; Chris Johnson, University of Northern British Columbia; Tom Johnston, Ontario Ministry of Natural Resources and Forestry/Laurentian University; Tom Jung, Government of Yukon; Ernest Keeley, Idaho State University; Nicola Koper, University of Manitoba; Piia Kukka, University of Alberta; Christopher Kyle, Trent University; Jeffery Larkin, Indiana University of Pennsylvania; Shawn Larson, Seattle Aquarium; Jim Leafloor, Canadian Wildlife Service; Lisa-Marie Leclerc, Government of Nunavut; Weiming Li, Michigan State University; Staffan Lindgren, University of Northern British Columbia; Todd Mahon, Edmonton AB; David Nagorsen, Victoria BC; Nicholas Mandrak, University of Toronto; Nigel Marley, United Kingdom; Catherine Meckleburg, Auke Bay AK; Randall F. Miller, New Brunswick Museum; W. A. Montevecchi, Memorial University of Newfoundland and Labrador; David Murray, University of Alaska; Fraser

Neave, Fisheries and Oceans Canada; Dianne R. Nelson, East Tennessee State University; Erica Newton, Ontario Ministry of Natural Resources and Forestry; Martyn Obbard, Ontario Ministry of Natural Resources and Forestry (retired); Colleen Olfenbittel, North Carolina Wildlife Research Commission; Ken Otter, University of Northern British Columbia; Kristiina Ovaska, Victoria BC; Brent Patterson, Ontario Ministry of Natural Resources and Forestry / Trent University (2); Tim Pearce, Carnegie Museum of Natural History (2); Bruce Pond, Ontario Ministry of Natural Resources and Forestry; Paul Pratt, Wheatley ON; Tanya Pulfer, Ontario Nature; Randall Reeves, Hudson QC; Darryl Reynolds, British Columbia Ministry of Forests, Lands and Natural Resource Operation; Tony Reznicek, University of Michigan; Jim Richards, Nunavut Bird Checklist; Mark Ridgway, Ontario Ministry of Natural Resources and Forestry; Mike Rodway, Gold Bridge BC; Rick Rosatte, Ontario Ministry of Natural Resources and Forestry; Dolph Schluter, University of British Columbia; Fred Schueler, Bishop Mills ON; Helen Schwantje, British Columbia Ministry of Forests, Lands and Natural Resource Operations; Spencer Sealy, University of Manitoba; David Seburn, Ottawa ON; Dale Seip, British Columbia Ministry of Environment; Philipp Semenchuk, University of Tromsø; Tamara Smith, US Fish and Wildlife Service; Tyler Smith, Agriculture and Agri-Food Canada; Stuart Slattery, Ducks Unlimited Canada; Michael Steele, Wilkes University; Tom Sullivan, University of British Columbia; Heidi Swanson, University of Waterloo; Tara Szkorupa, British Columbia Ministry of Forests, Lands and Natural Resource Operations; Ken Tape, University of Alaska – Fairbanks; Phil Ward, University of California Davis; Doug Watkinson, Fisheries and Oceans Canada; Dave Zanatta, Central Michigan University.

The journal was printed at Gilmore Printers, Ottawa. Thanks to Guylaine Duval of Gilmore Printers for overseeing production and printing. We are grateful to The Ottawa Field-Naturalists' Club President Fenja Brodo and the club's Board of Directors for their support of the journal. We are also grateful to all of the individual subscribers and authors who support our team as we strive to provide a high-quality scientific journal on natural history, field biology, and ecology. Finally, we thank our families/partners for being patient and supportive throughout many long days, evenings, and weekends of working on the journal.

DWAYNE LEPLITZKI and
CAROLYN CALLAGHAN,
Editors-in-Chief;
AMANDA MARTIN, *Assistant Editor*

News and Comment

Great Canadian Field-Naturalists	280
Great Canadian Field-Naturalists: James Fletcher	280
Great Canadian Field-Naturalists: John Macoun	281

Upcoming Meetings and Workshops

The Alberta Chapter of the Wildlife Society Conference — Entomological Society of America, Eastern Branch Meeting — Entomological Society of America, North Central Branch Meeting — Entomological Society of America, Southwestern Branch Meeting — US Regional Association of the International Association for Landscape Ecology Annual Meeting — American Ornithology Meeting 2018 – 2018 Northeast Natural History Conference — Annual Northeast Fish & Wildlife Conference	284
--	-----

James Fletcher Award Established	285
----------------------------------	-----

Book Reviews

BOTANY: Curieuses histoires de plantes du Canada, Tome 1: 1000-1670, Tome 2: 1670-1760, Tome 3: 1760–1867	286
ENTOMOLOGY: The Secret Life of Flies — Insects: Their Natural History and Diversity: With a Photographic Guide to Insects of Eastern North America, Second Edition, Revised and Updated	287
ORNITHOLOGY: Raptors: The Curious Nature of Diurnal Birds of Prey — The Australian Bird Guide	289
ZOOLOGY: Wolves of the Yukon	291
OTHER: Rise of the Necrofauna: The Science, Ethics and Risks of De-Extinction — The Magnificent Nahanni: The Struggle to Protect a Wild Place — Coexistence: The Ecology and Evolution of Tropical Biodiversity — The Eye of the Sandpiper: Stories from the Living World	293
NEW TITLES	297

Editors’ Report	301
-----------------	-----

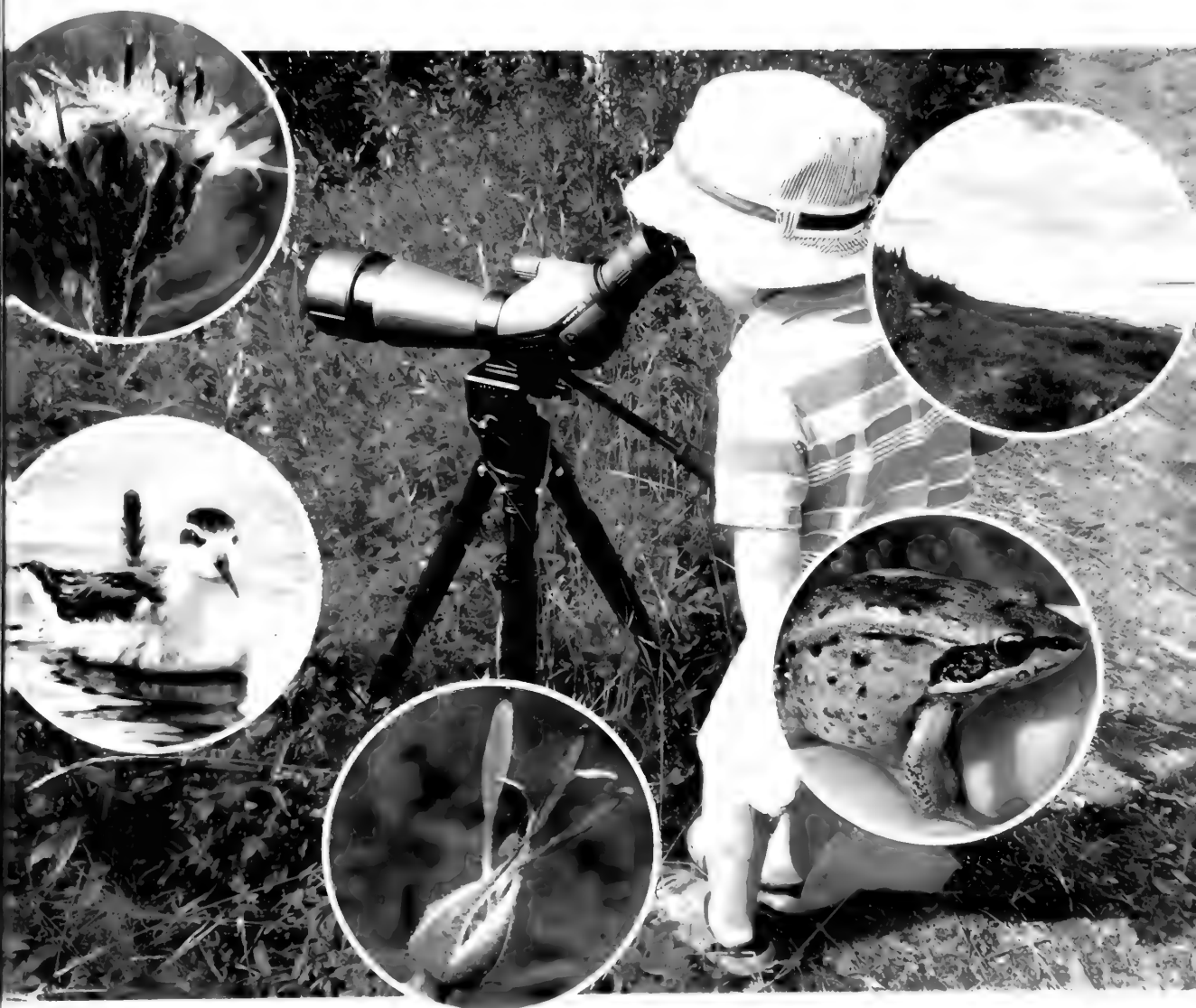
Mailing date of the previous issue 131(2): 1 December 2017

Annual and seasonal variation in shorebird abundance in the St. Lawrence River estuary during fall migration	YVES TURCOTTE, JEAN-FRANÇOIS LAMARRE, and JOËL BÉTY	203
Diet of Grey Wolves (<i>Canis lupus</i>) during calving in a Moose–Caribou system in northern Ontario	ROB FOUND, ASHLEY A. D. McLAREN, ARTHUR R. RODGERS, and BRENT R. PATTERSON	215
Observations of long-distance post-release dispersal by reintroduced bison (<i>Bison bison</i>)	THOMAS S. JUNG and NICHOLAS C. LARTER	221
Observations of notable parental behaviours of Northern Spotted Owls (<i>Strix occidentalis caurina</i>)	JESSE M. ALSTON, JANET E. MILLARD, JESSICA A. RICK, BRANDON W. HUSBY, and LAUREL A. MUNDY	225
Northern snakes appear much more abundant in old fields than in forests	FRANCISCO RETAMAL DIAZ and GABRIEL BLOUIN-DEMERS	228
Side to side swaying as a defensive behaviour in the Dekay's Brownsnake (<i>Storeria dekayi</i>)	DAVID L. LEGROS	235
Psychrotolerant microfungi associated with Deer Mice (<i>Peromyscus maniculatus</i>) in a white-nose syndrome positive bat hibernaculum in eastern Canada	KAREN J. VANDERWOLF, DAVID MALLOCH, and DONALD F. McALPINE	238
<i>Fabronia ciliaris</i> , a moss new to Canada from southeastern Manitoba	RICHARD T. CANERS	246
River Otter (<i>Lontra canadensis</i>) killed by wolves (<i>Canis lupus</i>) during winter in Northern Minnesota	THOMAS D. GABLE, STEVE K. WINDELS, and IAN C. RAUTIO	252
Adult Snapping Turtle (<i>Chelydra serpentina</i>) feeding on goldeneye embryos of Pumpkinseed (<i>Lepomis gibbosus</i>) in defended nests	ALEXANDER J. BUSE, MEGHAN A. DOUGLAS, THOMAS N. GIGUÈRE, and BEREN W. ROBINSON	254
Range extensions of 35 bryophyte species in the Black Spruce–feather moss forest of western Quebec, Canada	MARION BARBÉ, LOUIS DUBOIS, JEAN FAUBERT, MARTIN LAVOIE, YVES BERGERON, and NICOLE J. FENTON	258
Observations of beachcast Bowhead Whales (<i>Balaena mysticetus</i>) in the southeastern Beaufort Sea and Amundsen Gulf, 1987–2016	LOIS A. HARWOOD, ELLEN V. LEA, STEPHEN A. RAVERTY, PATRICIA A. HALL, ERIN LINN, LIANNE POSTMA, and OLE NIELSEN	270

(continued on inside back cover)

The CANADIAN FIELD-NATURALIST

A JOURNAL OF FIELD BIOLOGY AND ECOLOGY



Volume 131, Number 4

October–December 2017

Published by THE OTTAWA FIELD-NATURALISTS' CLUB, Ottawa, Canada

The Ottawa Field-Naturalists' Club

FOUNDED IN 1879

Patron

Her Excellency the Right Honourable Julie Payette, C.C., C.M.M., C.O.M., C.Q., C.D.
Governor General and Commander-in-Chief of Canada

The objectives of this Club shall be to promote the appreciation, preservation and conservation of Canada's natural heritage; to encourage investigation and publish the results of research in all fields of natural history and to diffuse information on these fields as widely as possible; to support and cooperate with organizations engaged in preserving, maintaining or restoring environments of high quality for living things.

Honorary Members

Ronald E. Bedford	Francis R. Cook	C. Stuart Houston	E. Franklin Pope
Charles D. Bird	Bruce Di Labio	Ross A. Layberry	Allan H. Reddoch
Fenja Brodo	Anthony J. Erskine	Robert E. Lee	Joyce M. Reddoch
Irwin M. Brodo	J. Bruce Falls	John McNeill	Dan Strickland
Daniel F. Brunton	Peter W. Hall	Theodore Mosquin	John B. Theberge
Michael D. Cadman	Christine Hanrahan	Robert W. Nero	Sheila Thomson
Paul M. Catling			

2017 Board of Directors

President: Diane Lepage	Annie Bélair	Diane Kitching	Jeffery M. Saarela
1st Vice-President: Jakob Mueller	Fenja Brodo	Dwayne Lepitzki	Henry Steger
Recording Secretary: Lynn Ovenden	Owen Clarkin	Rémy Poulin	Eleanor Zurbrigg
Treasurer: Ann MacKenzie	Edward Farnworth	Gordon Robertson	

To communicate with the Club, address postal correspondence to: The Ottawa Field-Naturalists' Club, P.O. Box 35069, Westgate P.O., Ottawa, ON, K1Z 1A2, or e-mail: ofnc@ofnc.ca. For information on Club activities, go to www.ofnc.ca

The Canadian Field-Naturalist

The Canadian Field-Naturalist is published quarterly by The Ottawa Field-Naturalists' Club. Opinions and ideas expressed in this journal do not necessarily reflect those of The Ottawa Field-Naturalists' Club or any other agency.

Website: www.canadianfieldnaturalist.ca/index.php/cfn

Editor-in-Chief: Dr. Dwayne Lepitzki

Copy Editors: Sandra Garland and Dr. John Wilmshurst

Book Review Editor: Barry Cottam

Subscription Manager: Eleanor Zurbrigg

Associate Editors:	Dr. Ron Brooks	Dr. Jennifer R. Foote	Jon McCracken	Dr. Jeffery M. Saarela
	Dr. Carolyn Callaghan	Dr. Graham Forbes	Dr. Garth Mowat	David C. Seburn
	Dr. Paul M. Catling	Thomas S. Jung	David Nagorsen	Dr. Jeffrey H. Skevington
	Dr. François Chapleau	Dr. Donald F. McAlpine	Dr. Marty Obbard	

Chair, Publications Committee: Dr. Jeffery M. Saarela

All manuscripts intended for publication except Book Reviews can be addressed to the Editor and sent by e-mail: editor@canadianfieldnaturalist.ca **or postal mail (with disk):** P.O. Box 1979, Banff, AB T1L 1B7; (403) 762-0864. Online submissions through the website are encouraged.

Book-review correspondence should be sent to the Book Review Editor by e-mail: b.cottam@rogers.com **or postal mail:** 98 Norman Street, Ottawa, ON K1S 3K6

Subscriptions and Membership:

Subscription rates for individuals are \$40 (online only), \$50 (print only), or \$60 (print + online). Libraries and other institutions may subscribe for \$120 (online only or print only) or \$180 (print + online). All foreign print subscribers and members (including USA) must add \$10 to cover postage. The Ottawa Field-Naturalists' Club annual membership fee of \$40 (individual), \$45 (family), or \$20 (student) includes an online subscription to *The Canadian Field-Naturalist*. Members can receive printed issues of CFN for an additional \$30 per volume (four issues). For further details, see <http://ofnc.ca/membership-and-donations>. The club's regional journal, *Trail & Landscape*, covers the Ottawa District and regional Club events and field trips. It is mailed to all club members. It is available to libraries at \$40 per year. Subscriptions, applications for membership, notices of changes of address, and undeliverable copies should be sent to subscriptions@canadianfieldnaturalist.ca or mailed to: The Ottawa Field-Naturalists' Club, P.O. Box 35069, Westgate P.O., Ottawa, ON, K1Z 1A2 Canada. Canada Post Publications Mail Agreement number 40012317. Return postage guaranteed.

The Thomas H. Manning fund, a special fund of the OFNC, established in 2000 from the bequest of northern biologist Thomas H. Manning (1911–1998), provides financial assistance for the publication of papers in the CFN by independent (non-institutional) authors, with particular priority given to those addressing arctic and boreal issues. Qualifying authors should make their application for assistance from the Fund at the time of their initial submission.

COVER: Northwest Territories BioBlitzes, 2017. See News and Comment, pages 386–396. Centre: spotting scope setup along the Boot Lake Trail in Inuvik illustrates the importance of BioBlitzes to children. Photo: Brenda Kostuik. The inset photos (counter clockwise from top left) are: Narrow-leaved Saw-wort (*Saussurea angustifolia*), Red-necked Phalarope (*Phalaropus lobatus*), Prickly Rose (*Rosa acicularis*), Wood Frog (*Lithobates sylvaticus*), and the MacKenzie River shoreline. Photos: Paul Catling.

Autumn Raptor Migration in Yellowstone National Park, 2011–2015

LISA M. BARIL¹, DAVID B. HAINES¹, LAUREN E. WALKER^{1,2}, and DOUGLAS W. SMITH¹

¹National Park Service, P.O. Box 168, Mammoth, Wyoming 82190 USA

²Corresponding author: lauren_walker@nps.gov

Baril, Lisa M., David B. Haines, Lauren E. Walker, and Douglas W. Smith. 2017. Autumn raptor migration in Yellowstone National Park, 2011–2015. *Canadian Field-Naturalist* 131(4): 303–311. <https://doi.org/10.22621/cfn.v131i4.1909>

Raptors are wide-ranging, vagile avian predators whose populations can be difficult and costly to monitor on their breeding or winter range. However, monitoring raptors during their annual northbound or southbound migration is a cost-effective and efficient alternative to time-intensive, single-species breeding surveys. In 2010, we observed numerous Swainson's Hawks (*Buteo swainsoni*) and Red-tailed Hawks (*Buteo jamaicensis*) migrating through the Hayden Valley in central Yellowstone National Park, prompting an investigation into raptor migration patterns in the park. Our objectives were to monitor annual autumn raptor migration in Hayden Valley from 2011 to 2015 and to determine the relative role of this undocumented migration site by comparing our observations to simultaneously collected migration data from three other sites in the Rocky Mountain Flyway. From 2011 to 2015, we observed 6441 raptors of 17 species across 170 d and 907 h of observation. Red-tailed Hawks, Swainson's Hawks, and Golden Eagles (*Aquila chrysaetos*) accounted for 51% of the total individuals observed over five years. Overall counts from Hayden Valley were comparable to counts from the three migration sites in the Rocky Mountains, although abundance of individual species varied by site. Data from this study suggest that Hayden Valley may serve as a stopover site for migrating raptors and presents an opportunity for future research. By improving our understanding of where raptors migrate and the characteristics of stopover areas in the Rocky Mountains, land managers may develop effective strategies for protecting raptor populations and habitat from threats including development and climate change.

Key Words: Migration; raptor; birds; Yellowstone National Park; Rocky Mountain Flyway; Wyoming

Introduction

Raptors are wide-ranging, vagile avian predators whose populations are difficult and costly to monitor using time-intensive, single-species surveys on their breeding or wintering grounds. However, as raptors concentrate along mountainous ridgelines during their annual northbound or southbound migration, counts of multiple raptor populations can be conducted simultaneously by relatively few personnel. Thus, migration offers a unique opportunity to assess raptor populations in a relatively efficient and cost-effective manner (Bildstein *et al.* 2007). Each year, millions of raptors migrate from their breeding areas to wintering grounds following traditional migratory pathways throughout North America (McCarty and Bildstein 2005). Along these corridors, observers have identified hundreds, or even thousands, of raptors across multiple species in individual seasons (Hoffman and Smith 2003; Lott 2006). Over time, these data have been used to detect trends in populations of individual species (Farmer *et al.* 2007; Bildstein *et al.* 2008), determine changes in the timing of migration (Jaffré *et al.* 2013), and identify important migratory pathways (Bedrosian *et al.* 2015).

Migration requires raptors to navigate long-distances through potentially risky terrain (e.g., wind farms; Johnston *et al.* 2013) and locate stopover areas with reliable sources of prey (Pocewicz *et al.* 2013; Vardanis *et al.* 2016). Many raptors migrate across international and

even continental boundaries (Kochert *et al.* 2011). For example, Swainson's Hawks (*Buteo swainsoni*) have one of the longest migration routes of any raptor in the world (Fuller *et al.* 1998; Bechard *et al.* 2010; Kochert *et al.* 2011). Each year tens of thousands of Swainson's Hawks leave their breeding grounds in west-central North America for wintering areas in the open grasslands or pampas of Argentina in South America, a roundtrip of over 20 000 km (Bechard *et al.* 2010; Kochert *et al.* 2011). Even short-distance migrants such as Golden Eagle (*Aquila chrysaetos*) and Rough-legged Hawk (*Buteo lagopus*) cross international boundaries from breeding areas in Alaska and Canada to wintering grounds throughout the western United States and Mexico (Bechard and Swem 2002; McIntyre *et al.* 2008).

In 2010, we observed a large number of Swainson's Hawks and Red-tailed Hawks (*Buteo jamaicensis*) migrating through Hayden Valley in central Yellowstone National Park (YNP), prompting further interest in local migration patterns. While much is known about the migratory paths of raptors in the eastern USA (McCarty and Bildstein 2005), comparatively little is known about the migratory paths and stopover areas of raptors that use the Rocky Mountain Flyway (Hoffman and Smith 2003; Bedrosian *et al.* 2015; Craighead *et al.* 2016). The complex topography of the Rocky Mountains results in a broad migratory front as raptors are dispersed along competing ridgelines, making it diffi-

cult to assess migration patterns in this area (Fuller *et al.* 1998; Lott and Smith 2006; Craighead *et al.* 2016). Thus, we were broadly interested in both contributing to the general knowledge of autumn raptor migration within the Rocky Mountain Flyway and determining the particular importance, if any, of YNP to migrating raptors. In this study, our objectives were to 1) monitor the annual autumn raptor migration in Hayden Valley in central YNP from 2011 to 2015 and 2) learn how species diversity and the timing of autumn migration at this previously undocumented migration site compared with data collected during the same period at three additional migration sites in the Rocky Mountain Flyway.

Study Area

We monitored raptor migration in the Hayden Valley of central YNP, Wyoming, USA (Figure 1) from atop a small hill approximately 0.5 km west of the road at 44.66°N, 110.47°W and at 2411 m elevation. The Hayden Valley is an approximately 75 km² subalpine valley located along the Yellowstone River. Vegetation in the bottomlands is dominated by Mountain Big Sagebrush (*Artemisia tridentata* var. *vaseyana* (Rydberg) B. Boivin), Silver Sagebrush (*Artemisia cana* Pursh), and Idaho Fescue (*Festuca idahoensis* Elmer), while Lodgepole Pine (*Pinus contorta* Douglas ex Loudon)

dominates the uplands (Despain 1990). Climate in the region is characterized by short summers with an average temperature of 11.8°C during July and long cold winters with an average temperature of −10.8°C in December (Crait and Ben-David 2006). The region receives an average of 513 mm of annual precipitation, most of which falls as snow during the winter (Crait and Ben-David 2006).

Hayden Valley is a low-lying sagebrush steppe grassland bounded to the north by the east-west trending Washburn Range and by large forested plateaus on either side of the valley (Despain 1990). As many migration observation sites are located along mountain peaks and ridgelines (Hoffman and Smith 2003), Hayden Valley is distinctly atypical. Raptors migrating south through Hayden Valley in autumn must pass over the Washburn Range at a mean elevation of 2808 m before entering the valley. Although Hayden Valley may not provide the typical orographic uplift (lift provided by a steep elevational gradient such as the edge of a mountain range) that concentrates raptors at many migration observation sites, the river valley and surrounding topography may provide thermal lift as well as foraging opportunities that may appeal to migrating raptors (Bildstein *et al.* 2007). Thus, this site provides a unique and potentially valuable vantage point to monitor raptor migration in the western United States.

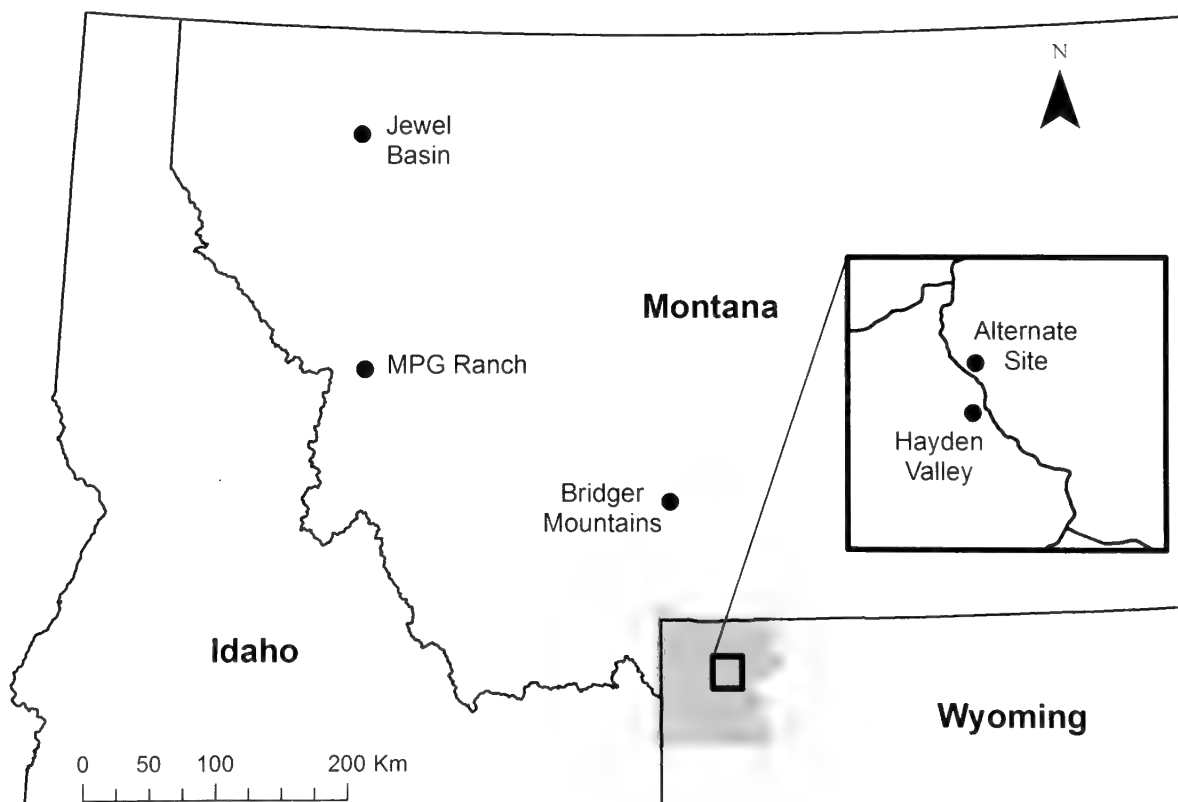


FIGURE 1. Location of raptor migration count sites in Yellowstone National Park (YNP; shaded grey), Wyoming, and three comparison sites in northern and western Montana. Exact locations of Hayden Valley count site and the alternate site are shown in the insert, along the Grand Loop Road through central YNP.

Methods

Data Collection

We monitored raptors during their southbound migration during September and October 2011–2015. Although the start and end dates varied by year, we generally began counts during the first week in September and continued through the third week in October. Beginning in late October, weather conditions in YNP generally prohibit travel throughout the southern portion of the park, including Hayden Valley. At the beginning of each autumn migration season, experienced counters trained observers in the field for a minimum of two weeks before observers were permitted to collect observation data on their own. Additionally, an experienced observer was present during counts at least three days per week and usually 4–5 days per week. We conducted counts a minimum of five days per week and observed for approximately 6 h per day, beginning at 1000 hours and ending at 1600 hours. Two to four primary observers conducted each daily count and dependent observers worked together to adequately cover the broad viewshed, avoid double-counting, and accurately identify raptors to species. On each count day, a single observer recorded all detections. We did not attempt to correct our observations for detectability. Occasionally additional observers joined the count efforts and the recorder noted this on the data sheet.

During each count, observers scanned the entire northern portion of the sky in a 180° arc and then scanned north in an up-and-down motion to cover the entire northern portion of the sky. Observers used 10×42 binoculars to detect raptors and a spotting scope with 20–60× magnification to identify individuals if necessary. We recorded all raptors observed moving past the site by species. Observers also scanned without optics, particularly when spotting raptors directly overhead or those close to the observation point. Observers recorded the start and end time of observation periods, which usually lasted the full day (6 h); however, occasional interruptions occurred as a result of weather (i.e., lightning, heavy rain, or snow) or wildlife (e.g., bears [*Ursus* spp.] or American Bison [*Bison bison*] near the count site). Observers also recorded weather data using a Kestrel 2500 Weather Meter (Nielsen-Kellermen, Chester, Pennsylvania, USA) at the start and end of each observation period, in addition to hourly intervals throughout the day. We collected weather data including sky condition (cloud type and percent cover), average wind speed (km h), maximum wind speed (km h), wind direction (degrees), temperature (°C), barometric pressure (mmHg), and an estimate of overall visibility distance (km) from the count site. For each hour of observation, observers also noted the number of observers, total number of minutes of observation for that hour, and primary horizontal movement of raptors (i.e., east, west, or overhead). At the end of each count day we summed the totals over all hours of observation and across all

species. We also calculated the observer effort for each count day (the number of observers multiplied by the number of survey hours).

Data Analysis

We summarized annual raptor counts and total observer effort (the sum of daily calculations of observer effort) for each study year. We also determined the average passage rate (the average number of raptors observed migrating over the count site per hour) for each of the five years and the average passage rate over the full time period. For species with more than 20 observations per year, we determined median and bulk passage dates over the five years. Bulk passage dates were defined as the range of dates between which the central 80% of the entire season's total for each species passed through the migration site (i.e., the first date is the date by which 10% of the season's cumulative sightings have been made and the last is the date by which 90% of the season's cumulative sightings have been made; Lott 2006).

Finally, we compared our migration count totals to counts from three additional sites in the Rocky Mountain Flyway, monitored during the same time period. All sites, including Jewel Basin, MPG Ranch, and Bridger Mountains, were located in Montana, USA, northwest of the Hayden Valley site (Figure 1). The three sites met the following criteria: 1) autumn migration data were collected from 2011 to 2015, 2) standard count procedures were used to collect migration data, and 3) permission was granted to use the data for comparisons with our dataset from YNP. To control for differences in the number of hours of observation among sites, and to make our data comparable to previous assessments of western raptor migration patterns (Hoffman and Smith 2003), we converted raptor observations to counts per 100 h of observation (raptors 100 observation hours = [total raptors counted total hours of observation] × 100). We compared total raptor counts per 100 observation hours across all sites from 2011 to 2015 as well as counts per 100 h for ten of the most common species recorded at Hayden Valley.

Results

Observation Effort and Count Totals

We observed migrating raptors on a total of 170 d during September and October 2011–2015 with an average of 34 d per season (Table 1). On average, we observed migrating raptors for 181 h per season with observer effort (hours × observers) averaging 490 h per season.

The Hayden Valley count site posed numerous challenges during the study period. In 2011, the area surrounding the count site was closed as a result of two fatal Grizzly Bear (*Ursus arctos*) attacks. Therefore, we conducted all observations in 2011 from an alternate count site located approximately 4 km north in Hayden Valley (Figure 1). This alternate site had a similar view to our standard count site; although a small portion of

TABLE 1. Effort expended at the migration count site during 2011–2015 in Hayden Valley, Yellowstone National Park.

	2011	2012	2013	2014	2015	Mean	Total
Days	35	38	22	40	35	34	170
Mean observers per day	2.53	2.79	2.81	2.86	2.49	2.70	2.70
# hours	177	202	116	222	190	181	907
Observer effort*	448	564	326	636	474	490	2448

*Mean number of observers × number of hours of observation.

the western viewshed was blocked by a small hill in the foreground, a one-day comparison-count between the two sites revealed remarkable similarity in species' composition and abundance. We acknowledge a one-day comparison may not fully represent the variability between these sites; however, we feel our observations from the alternate site are comparable to what we would have observed from the regular Hayden Valley site and thus have included these data in our analyses.

From 2012 to 2015, we generally conducted counts from the standard count site. In 2012, however, several fires burning in Idaho and in YNP severely reduced visibility at the standard count site and contributed to poor observing conditions. The United States government sequestration (a shutdown of all non-essential government activities, including national parks) in 2013 prevented observers from data collection in Hayden Valley beginning 1 October, effectively ending the migration monitoring season three weeks early. Finally, in 2015, we occasionally counted migrating raptors from the alternate site due to high Grizzly Bear use in the area of the standard count site.

Despite these difficulties, observers recorded 6441 raptors belonging to 17 species (Table 2). Three species (Red-tailed Hawk, Swainson's Hawk, and Golden Eagle) accounted for about half (51%) of the total birds

observed across all years. Red-tailed Hawk was by far the most numerous species across all years. We recorded fewer than 30 individuals per year for seven species of raptor, including Osprey (*Pandion haliaetus*), Turkey Vulture (*Cathartes aura*), Broad-winged Hawk (*Buteo platypterus*), Merlin (*Falco columbarius*), Northern Goshawk (*Accipiter gentilis*), Peregrine Falcon (*Falco peregrinus*), and Prairie Falcon (*Falco mexicanus*). Observers recorded the highest number of raptors in 2011 ($n = 1846$), most of which were Red-tailed Hawk, and the fewest in 2013 ($n = 717$).

Passage Rate and Timing

The average passage rate over the five years was 7 birds/h (Figure 2). During any given observation day, however, passage rate was lowest during the first hour of observation, peaked between 1100–1300 hours as air temperature increased, and thermals likely developed, and then tapered the rest of the day (Figure 2). Average passage rate was highest in 2011 (9.9 birds/h) and lowest in 2012 (4.8 birds/h).

Only seven species occurred with enough frequency to calculate average median and bulk passage dates (Table 3). We excluded 2013 data from this analysis because there was a 20-day period during which no data were collected. The bulk of raptors (80%) migrated

TABLE 2. Annual total, mean, coefficient of variation (CV), and proportion of raptors observed migrating through Hayden Valley in Yellowstone National Park during 2011–2015. Raptor species are sorted from highest to lowest number of observations.

Species	2011	2012	2013	2014	2015	Total	Mean	CV	% of Total
Red-tailed Hawk (<i>Buteo jamaicensis</i>)	571	235	177	382	402	1767	353	74	27
Swainson's Hawk (<i>Buteo swainsonii</i>)	357	46	171	208	68	850	170	123	13
Golden Eagle (<i>Aquila chrysaetos</i>)	241	134	35	187	105	702	140	95	11
American Kestrel (<i>Falco sparverius</i>)	73	62	64	155	104	458	92	73	7
Unidentified raptors	198	44	19	80	102	443	89	133	7
Sharp-shinned Hawk (<i>Accipiter striatus</i>)	65	72	68	109	80	394	79	38	6
Rough-legged Hawk (<i>Buteo lagopus</i>)	70	130	23	108	61	392	78	90	6
Northern Harrier (<i>Circus cyaneus</i>)	55	30	27	119	131	362	72	117	6
Bald Eagle (<i>Haliaeetus leucocephalus</i>)	93	68	26	95	60	342	68	70	5
Cooper's Hawk (<i>Accipiter cooperii</i>)	31	32	28	75	85	251	50	94	4
Ferruginous Hawk (<i>Buteo regalis</i>)	34	20	32	29	10	125	25	66	2
Osprey (<i>Pandion haliaetus</i>)	12	14	18	22	11	77	15	49	1
Turkey Vulture (<i>Cathartes aura</i>)	9	22	0	29	2	62	12	171	1
Broad-winged Hawk (<i>Buteo platypterus</i>)	0	7	1	35	9	52	10	234	1
Merlin (<i>Falco columbarius</i>)	13	11	6	12	7	49	10	53	1
Northern Goshawk (<i>Accipiter gentilis</i>)	10	7	9	14	3	43	9	78	1
Peregrine Falcon (<i>Falco peregrinus</i>)	10	8	8	7	5	38	8	40	1
Prairie Falcon (<i>Falco mexicanus</i>)	4	11	5	11	3	34	7	96	1
Total	1846	953	717	1677	1248	6441	1288	62	100

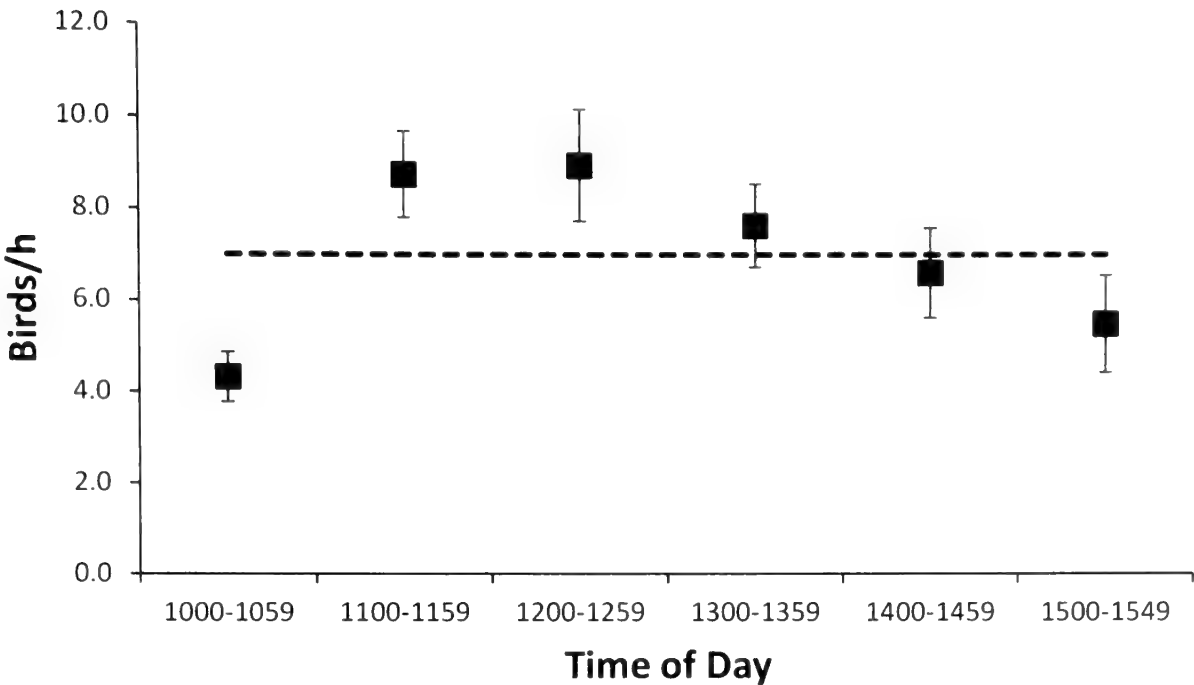


FIGURE 2. Mean hourly passage rate (birds/h) of raptors observed migrating through Hayden Valley in Yellowstone National Park during 2011–2015. Error bars are standard error and the horizontal dashed line is the overall average passage rate.

through Hayden Valley beginning in the first week in September through the third week in October. Although this roughly corresponds with our observation season, we saw a substantial decline in raptor observations by mid-October that suggests our season adequately captures the migration of most species through the study area. The bulk of Swainson’s Hawks passed through the migration site during September. The bulk of Northern Harriers (*Circus cyaneus*), Red-tailed Hawks, Cooper’s Hawks (*Accipiter cooperii*), and Sharp-shinned Hawks (*Accipiter striatus*) occurred from mid-September until mid-October. Golden Eagles and Rough-legged Hawks migrated primarily from early October through the end of our count period. Both Swainson’s Hawks and Rough-legged Hawks exhibited the shortest duration of migration through Hayden Valley, while Sharp-shinned

Hawks, Northern Harriers, and Red-tailed Hawks exhibited the longest migration through Hayden Valley.

Comparison to Other Migration Sites

Mean counts of raptors per 100 h of observation at Hayden Valley were comparable to counts per 100 h of observation at MPG Ranch and the Bridger Mountains, while Jewel Basin surpassed all three sites (Table 4). For individual species, Hayden Valley exhibited the highest Swainson’s Hawk, Rough-legged Hawk, Northern Harrier, Bald Eagle (*Haliaeetus leucocephalus*), Ferruginous Hawk (*Buteo regalis*), and Red-tailed Hawk counts after controlling for hours of observation (Table 5). The average number of American Kestrel (*Falco sparverius*) and Cooper’s Hawk was somewhat comparable to the other sites, but far fewer Golden Eagles and Sharp-shinned Hawks migrated

TABLE 3. Bulk passage dates summarized from 2011–2015, including 80% passage date range and median date, for migrating raptors with more than 20 observations per year at Hayden Valley, Yellowstone National Park. Standard deviations (SD) are given for the number of days over which 80% of birds were observed and for the median passage date.

Species	80% passage dates	Days	SD	Median date	SD
Swainson’s Hawk (<i>Buteo swainsonii</i>)	7 Sep–19 Sep	12	4	13 Sep	5
American Kestrel (<i>Falco sparverius</i>)	8 Sep–30 Sep	24	5	19 Sep	3
Northern Harrier (<i>Circus cyaneus</i>)	10 Sep–13 Oct	33	8	27 Sep	5
Cooper’s Hawk (<i>Accipiter cooperii</i>)	14 Sep–11 Oct	27	7	28 Sep	3
Sharp-shinned Hawk (<i>Accipiter striatus</i>)	11 Sep–18 Oct	37	5	29 Sep	4
Red-tailed Hawk (<i>Buteo jamaicensis</i>)	13 Sep–15 Oct	32	7	5 Oct	7
Golden Eagle (<i>Aquila chrysaetos</i>)	1 Oct–20 Oct	20	5	10 Oct	3
Rough-legged Hawk (<i>Buteo lagopus</i>)	10 Oct–22 Oct	12	2	16 Oct	4

TABLE 4. Total individual raptors counted per 100 hours of observation for four migration sites in the Rocky Mountain Flyway. Counts for Hayden Valley (this study) are shown in bold.

Year	Jewel*	MPG†	Bridger‡	Hayden§
2011	889	498	696.0	1042
2012	831	570	680.0	472
2013	721	1175	689.0	618
2014	983	778	720.0	755
2015	1090	862	822.0	657
Mean	903	777	721.4	709

*Jewel Basin, Montana; data provided and used with permission by Daniel Casey (Flathead Audubon, Montana and American Bird Conservancy).

†MPG Ranch, Montana; data provided and used with permission by Adam Shreading (Raptor View Research).

‡Bridger Mountains, Montana; data provided and used with permission by Steve Hoffman (Montana Audubon and Hawkwatch International).

§Hayden Valley, Wyoming.

through Hayden Valley than the other sites, with the exception of Golden Eagles at MPG Ranch. Counts from Hayden Valley were most similar to MPG Ranch.

Discussion

We conducted autumn counts of migrating raptors from 2011 to 2015 in Hayden Valley, Yellowstone National Park. Hayden Valley is a broad grassland river valley, atypical among migration observation sites. Furthermore, as the first effort to evaluate raptor migration in Yellowstone, this study helps fill both a geographic and topographic gap in our knowledge of raptor migration in the western United States. Our observations, including 6441 individuals belonging to 17 raptor species, were consistent to those from other migration count sites within the Rocky Mountain Flyway.

Our observations of bulk passage date indicate that, while our observation season likely captured the major-

ity of autumn raptor migration, we may have truncated observations for some species by ending our season in late October. Several species, notably Rough-legged Hawks and Golden Eagles, were still migrating in the third week in October when our counts ended and may continue their migration through early December (McIntyre *et al.* 2008). Raptor observation in the southern portion of Yellowstone becomes logistically difficult after late October due to inclement weather and road closures. Additionally, both Rough-legged Hawks and Golden Eagles are residents in Yellowstone during the winter and it can be difficult to distinguish between migrants and residents in late autumn. However, extending the season into early November would be consistent with other autumn migration monitoring stations in the western United States (Hoffman and Smith 2003). Thus, we recommend that, if migration observation continues in Hayden Valley, future counts should consider a longer observation season, when possible, to better capture the migration patterns of all species. A longer observation season, combined with a long term dataset, may also help capture climate change effects on the timing of migration. For example, on Lake Superior, along the northern United States border, long spring and autumn migration monitoring periods revealed that the median raptor migration date advanced in spring and was delayed in autumn, and that these effects were particularly strong for short-distance migrants including Bald Eagle, Northern Harrier, and Sharp-shinned Hawk (Buskirk 2012).

During our study, a number of factors disrupted counts and resulted in inconsistent data collection methods. In 2011 and 2015, we were forced to count from an alternate site and, in 2012, fires reduced visibility and likely affected the overall count. In 2013, the United States government sequestration forced an early end to the season. Despite these factors, the number of raptors counted at Hayden Valley from the standard and alter-

TABLE 5. Raptor species counted per 100 hours of observation for four migration sites in the Rocky Mountain Flyway. Counts for Hayden Valley (this study) are shown in bold.

Species	Jewel*	MPG†	Bridger‡	Hayden§
Red-tailed Hawk (<i>Buteo jamaicensis</i>)	72	190	64	195
Swainson’s Hawk (<i>Buteo swainsonii</i>)	0	5	1	94
Golden Eagle (<i>Aquila chrysaetos</i>)	162	17	316	77
American Kestrel (<i>Falco sparverius</i>)	24	64	34	50
Sharp-shinned Hawk (<i>Accipiter striatus</i>)	412	98	125	43
Rough-legged Hawk (<i>Buteo lagopus</i>)	7	31	14	43
Northern Harrier (<i>Circus cyaneus</i>)	14	31	21	40
Bald Eagle (<i>Haliaeetus leucocephalus</i>)	15	16	21	38
Cooper’s Hawk (<i>Accipiter cooperii</i>)	126	50	55	28
Ferruginous Hawk (<i>Buteo regalis</i>)	0	1	1	14

*Jewel Basin, Montana; data provided and used with permission by Daniel Casey (Flathead Audubon, Montana and American Bird Conservancy).

†MPG Ranch, Montana; data provided and used with permission by Adam Shreading (Raptor View Research).

‡Bridger Mountains, Montana; data provided and used with permission by Steve Hoffman (Montana Audubon and Hawkwatch International).

§Hayden Valley, Wyoming.

nate count sites was similar to counts at the Bridger Mountains and the MPG Ranch monitoring sites. The relative abundance of individual species, however, varied by survey location, highlighting the importance of the information provided by this previously unmonitored migration site.

The number of Red-tailed Hawks was similar between Hayden Valley and the MPG Ranch, but was considerably higher than for Jewel Basin and the Bridger Mountains. While Swainson's Hawks were considerably more abundant at Hayden Valley than at the other three locations, fewer Golden Eagles were observed migrating through Hayden Valley than at Jewel Basin or the Bridger Mountains. The latter site was established primarily because of the large number of Golden Eagles observed migrating there (S. Hoffman, personal communication).

Golden Eagles rely more on orographic uplift during autumn migration than other raptors (Katzner *et al.* 2012). Because the Bridger Mountain site and the Jewel Basin migration site are located on a peak along a ridgeline, these sites are likely to offer more orographic lift than the low-lying Hayden Valley where thermals are more likely to develop (Katzner *et al.* 2012). Conversely, Red-tailed and Swainson's Hawks tend to rely more on thermal uplift (Preston and Beane 2009; Bechard *et al.* 2010), which probably explains the large number of those species observed in Hayden Valley. More buteos were observed migrating through Hayden Valley compared with the other comparison sites, suggesting that Hayden Valley may provide unique features required for some raptors and counts here may better represent migration patterns for these species.

In 2011, we observed the highest total number of raptors during the five years of surveys. This was surprising considering the viewshed at the alternate site was partially blocked to the west. We suspect, however, that at least some of the Swainson's and Red-tailed Hawks observed during 2011 were counted more than once. At the standard count site during subsequent years, observers noticed that as some raptors entered the valley from the north, they then descended into the valley and began making wide circular flights while foraging. From the standard count site, it was easier for observers to notice this pattern because the site was set farther back in the valley and the viewshed was larger. In the future, we may improve upon our count estimates and better detect differences among observation sites by conducting more rigorous counting protocols or analyses (e.g., independent observers or calculating detection probabilities).

Although foraging raptors may have led to an overestimation of the number of individuals passing through Hayden Valley in 2011, it also suggests that Hayden Valley may provide key foraging opportunities and serve as a valuable stopover location for migrating raptors. Stopover areas are important for raptors to rest, forage and replenish fat reserves, and to complete molt

(Kirby *et al.* 2008; Kochert *et al.* 2011; Pocewicz *et al.* 2013; Craighead *et al.* 2016; Vardanis *et al.* 2016). Hayden Valley represents an undisturbed region within the Rocky Mountain Flyway in which raptors may recuperate after long flights. Although no formal studies have been conducted, observers witnessed numerous foraging events during most survey days, most commonly in the morning hours. Additionally, there appears to be an abundance of grasshoppers and other insects as well as a high small mammal population upon which Swainson's Hawks and other raptors may forage (Sherrrod 1978; Schmutz *et al.* 1980; Johnson *et al.* 1987; Bednarz 1988; Woodbridge *et al.* 1995).

Migratory birds spend much of their annual life cycle travelling between their breeding grounds and wintering ranges, and migration can incur a high cost (Kirby *et al.* 2008). Mortality is six times greater during migration than during other times of the year, and time spent on migration accounts for half of all raptor mortality (Klaassen *et al.* 2014). Understanding where individual species migrate and identifying vital stopover areas is essential for developing effective management strategies for vulnerable or declining raptor populations. The data collected in this study may provide a baseline for comparison with future raptor migration studies. We found that a large number of raptors migrate through Hayden Valley in YNP during autumn and future investigations should further evaluate this region's importance as a stopover location for raptors using the Rocky Mountain Flyway, especially Swainson's Hawks and other buteos. Additionally, further collaboration among regional partners and landowners may help elucidate trends in raptor migration patterns throughout the Rocky Mountain region, identify key habitats that support migrating raptors, and develop more effective raptor management plans in the face of a developing landscape and warming climate.

Acknowledgements

We thank Yellowstone Forever (formerly known separately as the Yellowstone Park Foundation and the Yellowstone Association) for funding and administrative support. We particularly thank Bob and Annie Graham for their generous donation in support of this project and other raptor work in Yellowstone National Park. We thank volunteers and staff Amanda Boyd, Brenna Cassidy, Charlotte Chesney, Katy Duffy, Kathy Hixson, Rohan Kensey, Jeep Pagel, Chad Stachowiak, Lisa Strait, and Angela Woodside, as well as many other volunteers and visitors. Finally, we thank Rob Domech and Adam Shreading of Raptor View Research, Dan Casey of Flathead Audubon, Montana and American Bird Conservancy, and Steve Hoffman of Montana Audubon and Hawkwatch International for access to the comparison datasets from MPG Ranch, Jewel Basin, and the Bridger Mountains, respectively. We thank Steve Hoffman additionally for his 2014 insight into the Bridger Mountains site selection.

Literature Cited

- Bechard, M. J., and T. R. Swem.** 2002. Rough-legged Hawk (*Buteo lagopus*). In *The Birds of North America Online*. Edited by P. G. Rodewald. Cornell Lab of Ornithology, Ithaca, New York. Accessed 16 October 2016. <https://birdsna.org/Species-Account/bna/species/rolhaw>.
- Bechard, M. J., C. S. Houston, J. H. Saransola, and A. S. England.** 2010. Swainson's Hawk (*Buteo swainsoni*). In *The Birds of North America Online*. Edited by P. G. Rodewald. Cornell Lab of Ornithology, Ithaca, New York. Accessed 15 October 2016. <https://birdsna.org/Species-Account/bna/species/swahaw>.
- Bednarz, J. C.** 1988. A comparative study of the breeding ecology of Harris' and Swainson's hawks in southeastern New Mexico. *The Condor* 90: 311–323. <https://doi.org/10.2307/1368559>
- Bedrosian, B. E., S. L. Cain, S. Wolff, and D. J. Craighead.** 2015. Migratory pathways, timing, and home ranges of southern Greater Yellowstone Osprey. *Journal of Raptor Research* 49: 325–332. <https://doi.org/10.3356/JRR-14-42.1>
- Bildstein, K. L., J. P. Smith, E. Ruelas Inzunza, and R. R. Veit.** 2008. State of North America's Birds of Prey. Nuttall Ornithological Club and American Ornithologists' Union Series in Ornithology No. 3. Cambridge, Massachusetts and Washington, DC, USA.
- Bildstein, K. L., J. P. Smith, and R. Yosef.** 2007. Migration counts and monitoring. Pages 101–115 in *Raptor Research and Management Techniques*. Edited by D. M. Bird and K. L. Bildstein. Hancock House Publishers, Washington, DC, USA.
- Buskirk, J. V.** 2012. Changes in the annual cycle of North American raptors associated with recent shifts in migration timing. *The Auk* 129: 691–698. <https://doi.org/10.1525/auk.2012.12061>
- Craighead, D., R. H. Crandall, R. N. Smith, and S. L. Cain.** 2016. Migration of Red-tailed Hawks (*Buteo jamaicensis*) from northwest Wyoming. *Wilson Journal of Ornithology* 128: 150–158. <https://doi.org/10.1676/wils-128-01-150-158.1>
- Crait, J. R., and M. Ben-David.** 2006. River otters in Yellowstone Lake depend on a declining cutthroat trout population. *Journal of Mammalogy* 87: 485–494. <https://doi.org/10.1644/05-MAMM-A-205R1.1>
- Despain, D.** 1990. *Yellowstone vegetation: consequences of environment and history in a natural setting*. Roberts Rinehart Press, Boulder, Colorado, USA.
- Farmer, C. J., D. J. T. Hussell, and D. Mizrahi.** 2007. Detecting population trends in migratory birds of prey. *The Auk* 124: 1047–1062. [https://doi.org/10.1642/0004-8038\(2007\)124\[1047:DPTIMB\]2.0.CO;2](https://doi.org/10.1642/0004-8038(2007)124[1047:DPTIMB]2.0.CO;2)
- Fuller, M. R., W. S. Seegar, and L. S. Schueck.** 1998. Routes and travel rates of migrating Peregrine Falcons *Falco peregrinus* and Swainson's Hawks *Buteo swainsoni* in the western hemisphere. *Journal of Avian Biology* 29: 433–440. <https://doi.org/10.2307/3677162>
- Hoffman, S. W., and J. P. Smith.** 2003. Population trends of migratory raptors in western North America, 1977–2001. *The Condor* 105: 397–419. <https://doi.org/10.1650/7146>
- Jaffré, M., G. Beaugrand, É. Goberville, F. Jiguet, N. Kjellén, G. Troost, P. J. Dubois, A. Leprêtre, and C. Luczak.** 2013. Long-term phenological shifts in raptor migration and climate. *PLoS ONE* 8: e79112. <https://doi.org/10.1371/journal.pone.0079112>
- Johnston, N. N., J. E. Bradley, A. C. Pomeroy, and K. A. Otter.** 2013. Flight paths of migrating Golden Eagles and the risk associated with wind energy development in the Rocky Mountains. *Avian Conservation and Ecology* 8(2): 12. <https://doi.org/10.5751/ACE-00608-080212>
- Johnson, C. G., L. A. Nickerson, and M. J. Bechard.** 1987. Grasshopper consumption and summer flocks of non-breeding Swainson's Hawks. *The Condor* 89: 676–678. <https://doi.org/10.2307/1368663>
- Katzner, T. E., D. Brandes, T. Miller, M. Lanzone, C. Maisonneuve, J. A. Tremblay, R. Mulvihill, and G. T. Merovich, Jr.** 2012. Topography drives migratory flight altitude of Golden Eagles: implications for on-shore wind energy development. *Journal of Applied Ecology* 49: 1178–1186. <https://doi.org/10.1111/j.1365-2664.2012.02185.x>
- Kirby, J. S., A. J. Stattersfield, S. H. M. Butchart, M. I. Evans, R. F. A. Grimmett, V. R. Jones, J. O'Sullivan, G. M. Tucker, and I. Newton.** 2008. Key conservation issues for migratory land- and waterbird species on the world's major flyways. *Bird Conservation International* 18: S49–S73. <https://doi.org/10.1017/S0959270908000439>
- Klaassen, R. H. G., M. Hake, R. Strandberg, B. J. Koks, C. Trierweiler, K. Exo, F. Bairlein, and T. Alerstam.** 2014. When and where does mortality occur in migratory birds? Direct evidence from long-term satellite tracking of raptors. *Journal of Animal Ecology* 83: 176–184. <https://doi.org/10.1111/1365-2656.12135>
- Kochert, M. N., M. R. Fuller, L. S. Schueck, L. Bond, M. J. Bechard, B. Woodbridge, G. L. Holroyd, M. S. Martell, and U. Banasch.** 2011. Migration patterns, use of stop-over areas, and austral summer movements of Swainson's Hawks. *The Condor* 113: 89–106. <https://doi.org/10.1525/cond.2011.090243>
- Lott, C. A.** 2006. A new raptor migration monitoring site in the Florida Keys: counts from 1999–2004. *Journal of Raptor Research* 40: 200–209. [https://doi.org/10.3356/0892-1016\(2006\)40\[200:ANRMMS\]2.0.CO;2](https://doi.org/10.3356/0892-1016(2006)40[200:ANRMMS]2.0.CO;2)
- Lott, C. A., and J. P. Smith.** 2006. A geographic-information-system approach to estimating the origin of migratory raptors in North America using stable hydrogen isotope ratios in feathers. *The Auk* 123: 822–835. [https://doi.org/10.1642/0004-8038\(2006\)123\[822:AGATET\]2.0.CO;2](https://doi.org/10.1642/0004-8038(2006)123[822:AGATET]2.0.CO;2)
- McCarty, K., and K. L. Bildstein.** 2005. Using autumn hawk watch to track raptor migration and to monitor populations of North American birds of prey. Pages 718–725 in *Bird Conservation Implementation and Integration in the Americas: Proceedings of the Third International Partners in Flight Conference, Volume 2*. Edited by C. J. Ralph and T. D. Rich. General Technical Report PSW-GTR-191. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, California, USA.
- McIntyre, C. L., D. C. Douglas, and M. W. Collopy.** 2008. Movements of Golden Eagles (*Aquila chrysaetos*) from interior Alaska during their first year of independence. *The Auk* 125: 214–224. <https://doi.org/10.1525/auk.2008.125.1.214>
- Pocewicz, A., W. A. Estes-Zumpf, M. D. Andersen, H. E. Copeland, D. A. Keinath, and H. R. Griscom.** 2013. Modeling the distribution of migratory bird stopovers to inform landscape-scale siting of wind development. *PLoS ONE* 8: e75363. <https://doi.org/10.1371/journal.pone.0075363>

- Preston, C. R., and R. D. Beane.** 2009. Red-tailed Hawk (*Buteo jamaicensis*). In *The Birds of North America Online*. Edited by P. G. Rodewald. Cornell Lab of Ornithology, Ithaca, New York. Accessed 15 October 2016. <https://birdsna.org/Species-Account/bna/species/rethaw>.
- Schmutz, J. K., S. M. Schmutz, and D. A. Boag.** 1980. Coexistence of three species of hawks (*Buteo* spp.) in the prairie-parkland ecotone. *Canadian Journal of Zoology* 58: 1075–1089. <https://doi.org/10.1139/z80-151>
- Sherrod, S. K.** 1978. Diets of North American Falconiformes. *Raptor Research* 12: 49–121.
- Vardanis, Y., J. Nilsson, R. H. G. Klaassen, R. Strandberg, and T. Alerstam.** 2016. Consistency in long-distance bird migration: contrasting patterns in time and space for two raptors. *Animal Behavior* 113: 177–187. <https://doi.org/10.1016/j.anbehav.2015.12.014>
- Woodbridge, B., K. K. Finley, and S. T. Seager.** 1995. An investigation of the Swainson's Hawk in Argentina. *Journal of Raptor Research* 29: 202–204.

Received 17 February 2017

Accepted 18 October 2017

Sora (*Porzana carolina*) Parasitism of Red-winged Blackbird (*Agelaius phoeniceus*) Nests

LAWRENCE D. IGL

United States Geological Survey, Northern Prairie Wildlife Research Center, 8711 37th Street SE, Jamestown, North Dakota 58401-7317 USA; email: ligl@usgs.gov

Igl, Lawrence D. 2017. Sora (*Porzana carolina*) parasitism of Red-winged Blackbird (*Agelaius phoeniceus*) nests. *Canadian Field-Naturalist* 131(4): 312–316. <https://doi.org/10.22621/cfn.v131i4.1898>

Sora (*Porzana carolina*) is a conspecific brood parasite that also occasionally parasitizes nests of other species. Sora parasitism in nests of passerines is rare. Of 129 Red-winged Blackbird (*Agelaius phoeniceus*) nests found in North Dakota in 2009 and 2010, two (1.6%) were parasitized by Soras. The conditions favouring this rare parasitic behaviour may include competition for nest sites and high Sora density.

Key Words: Sora; *Porzana carolina*; Red-winged Blackbird; *Agelaius phoeniceus*; brood parasitism; North Dakota

Introduction

Conspecific brood parasitism has been reported in various bird taxa and over 230 bird species (Davies 2000; Yom-Tov 2001; Lyon and Eadie 2008). This behaviour is more prevalent among avian species with precocial young than in species with altricial young (Rohwer and Freeman 1989; Lyon and Eadie 2008). Conspecific parasitism has been described in territorial rails, including Sora (*Porzana carolina*; Allen 1939; Sorenson 1995) and several species of moorhens (*Gallinula angulata*, *G. chloropus*, *G. galeata*; Gibbons 1986; Ueda *et al.* 1993; McRae 1996; Jamieson *et al.* 2000; Post and Seals 2000) and coots (*Fulica americana*, *F. armillata*, *F. atra*, *F. cristata*, *F. rufifrons*; Arnold 1987; Lyon 1993; Jamieson *et al.* 2000; Lyon and Eadie 2004; Samraoui and Samraoui 2007).

Although the extent of this reproductive behaviour in Soras is poorly known, Sora hosts are known to exhibit conspecific egg discrimination and rejection (Sorenson 1995), a rare defensive tactic to mitigate the costs of conspecific brood parasitism (Davies 2000; Lyon 2003). There are also reports of heterospecific brood parasitism in Soras, including Soras laying eggs in nests of other rail species, e.g., Virginia Rail (*Rallus limicola*; Tanner and Hendrickson 1954), King Rail (*R. elegans*; Swales 1896), and other rail species laying eggs in Sora nests, e.g., Virginia Rail (Miller 1928). Sora parasitism in nests of non-rallid taxa has been reported once (Gollop 1949). Here, I report the second and third records of Soras parasitizing nests of a passerine, Red-winged Blackbird (*Agelaius phoeniceus*).

Observations

In 2009 and 2010, during a study of the immune system of the brood-parasitic Brown-headed Cowbird (*Molothrus ater*), observers located nests of a common cowbird host, the Red-winged Blackbird (hereafter redwing), at an experimental wetland facility maintained by the United States Geological Survey's Northern Prairie Wildlife Research Center, about 3 km east of

Jamestown (46°53'N, 98°38'W) in south-central North Dakota.

The facility consisted of 20 constructed earthen wetlands arranged in a four by five array covering an upland and wetland area of 2.66 ha. Individual wetland cells were approximately 22 × 22 m (0.05 ha) in flooded surface area, 1.2 m in maximum depth, and contoured to a 1:4 basin slope. Wetland plant communities were well established in the experimental wetlands, and the dominant emergent was cattails (*Typha* spp.), which occurred mainly in dense monospecific stands. These wetlands were functioning much like natural semi-permanent prairie wetlands.

Between late May and early July in both 2009 and 2010, observers visited the experimental wetlands at 1–4 day intervals to locate active redwing nests. Nests were located by flushing females from nests while walking along the adjacent upland berms or wading into the flooded cattails of each wetland cell. Each cell was occupied by one or two territorial male redwings and one to four female redwings. Knowledge of behavioural cues of nesting redwings and the small size of the wetland cells allowed observers to find a large number of redwing nests: 129 total nests (56 in 2009 and 73 in 2010). Redwing nests were built 5–65 cm (average 34.3 cm) above the water in cattails. Water depth beneath redwing nests was 10–94 cm (average 38.2 cm). Cowbird parasitism in redwing nests was moderate (25%) in 2009 and low (< 5%) in 2010; such variation between years is not unusual (Igl and Johnson 2007).

Observers found 26 active Sora nests (14 in 2009 and 12 in 2010; up to three per wetland cell) incidentally while searching for redwing nests. Sora nests were crudely woven platforms constructed of cattail stalks and leaves and attached at the base of live and senescent cattails; the lips of the nest platforms were 3–12 cm (average 6.6 cm) above the standing water (nest cup depth was not measured). Water depth beneath Sora nests was 0–70 cm (average 26.1 cm). Sora nests contained 6–16 Sora eggs (average 8.3 eggs per clutch),

although individual clutch sizes may have been underestimated if incomplete or partly hatched clutches were mistaken for full clutches. Most Sora nests were not systematically monitored after initial discovery.

Two (1.6%) of the 129 redwing nests contained the equivalent of full redwing clutches and a single Sora egg. During the morning of 7 June 2009, a female redwing was flushed from a nest containing five redwing eggs and one Sora egg (Figure 1). The Sora egg was not present six days earlier when this nest was first located with a single redwing egg. No Sora nests were located in this wetland cell in 2009, but Sora nests were found in three adjacent wetland cells that year. The nearest known Sora nest was about 27 m from the parasitized redwing nest and contained 16 Sora eggs, which is a large clutch for this species and may reflect conspecific parasitism by one or more Sora females. The parasitized redwing nest was 61 cm above the water, and the water depth beneath the nest was 94 cm. Cattail density in the vicinity of the nest was sparse. Both redwing eggs and the Sora egg were candled to determine viability and incubation stage and to estimate hatching dates (Weller 1956; Lokemoen and Koford 1996). Embryo development suggested that the redwing eggs and the

Sora egg had been incubated for about three days, indicating that the Sora egg had been deposited before the host's clutch was completed. Using published estimates of incubation stages for the redwing (11–13 days; Yasukawa and Searcy 1995) and Sora (16–20 days; Melvin and Gibbs 2012), the hatching dates were estimated to be 14–16 June and 19–23 June for the redwing eggs and the Sora egg, respectively. These estimates were based on the assumption that the Sora's larger egg (Figure 1) would not interfere with the length of the incubation period for the redwing eggs or their hatchability.

After discovery of the Sora egg in this nest, the redwing nest was visited almost daily until its fate was known. By mid-morning on 15 June, three of the five redwing eggs had hatched. On 16 June, the nest contained four redwing nestlings, a redwing egg, and the Sora egg; candling on that day indicated that the Sora embryo was in an advanced stage of development. On 18 June, the remaining redwing egg was missing, but the Sora egg remained. On 22 June, the nest contained three redwing nestlings and half of a Sora eggshell with a slightly detached membrane, suggesting that the Sora egg had hatched. A dead Sora hatchling and a dead red-



FIGURE 1. Red-winged Blackbird (*Agelaius phoeniceus*) nest parasitized by a Sora (*Porzana carolina*) in June 2009 in south-central North Dakota. Photo: L. D. Igl.

wing nestling were found floating in the water beneath the nest. Neither had visible injuries, and it is uncertain why they were dispelled from the nest. The three remaining redwing nestlings fledged from the nest on 25 or 26 June.

On 19 June 2010, a redwing nest was found with one redwing egg, one Sora egg, and three redwing nestlings that were approximately nine days old. Both eggs were heavily encrusted with bird excrement. The nest was 46 cm above the water, and the water depth beneath it was about 70 cm. Candling revealed no evidence of embryo development in the redwing egg; the Sora egg appeared to be addled (fertile but decomposing). A Sora nest with eight eggs was located in the same wetland cell, about 2.5 m east of the parasitized redwing nest. On 21 June, three newly fledged redwing young were perched near the redwing nest. The redwing egg disappeared from the nest between 26 and 28 June, and the Sora egg disappeared on 29 or 30 June. This nest was about 150 m from the parasitized redwing nest found in 2009; there was no evidence (e.g., egg size, shape, maculation) to suggest that the two Sora eggs found in the redwing nests in 2009 and 2010 were laid by the same female Sora.

Discussion

Reports of precocial species of rails laying eggs in nests of altricial or semi-altricial species are rare, e.g., American Coots (*F. americana*) parasitizing Least Bittern (*Ixobrychus exilis*) nests (Peer 2006); and Common Moorhen (*G. chloropus*) parasitizing Yellow Bittern (*I. sinensis*) nests (Ueda and Narui 2004). Reports of rails laying eggs in passerine nests are even rarer, with only two known cases previously reported in the literature. In South Carolina, Post and Seals (1989) found a Common Moorhen egg in a Boat-tailed Grackle (*Quiscalus major*) nest containing three host eggs. Gollop (1949) found a redwing nest with three host eggs and a Sora egg in southern Quebec. Given the numerous studies of redwing nesting biology in North America and the scarcity of similar parasitism records in the literature, Sora parasitism of redwing nests is undoubtedly rare.

Although Soras and redwings occupy the same marsh habitats during the breeding season, the two species have strikingly different nesting biologies and life history strategies, with little or no overlap in clutch size, nest type and location, nest dimensions and height, egg colour and size, onset and length of incubation, parental care, and discrimination of foreign eggs (Walkinshaw 1940, 1957; Yasukawa and Searcy 1995; Melvin and Gibbs 2012). The differences between the two species highlight the unusualness of these cases of heterospecific parasitism. Sora is a monogamous, solitary-nesting rail, and the redwing is a polygynous, colonial-nesting passerine. Redwings build open, cup-shaped nests 20–80 cm above the water surface in wetland emergent vegetation, and Soras build loosely woven nest plat-

forms over shallow water. Soras typically lay 8–11 buff-coloured eggs (average length 32.0 mm, average breadth 22.8 mm) that are irregularly spotted with brown or russet (Figure 1). Redwings lay four or five pale blue-green to grey eggs (average length 24.7 mm, average breadth 17.8 mm) that are irregularly (sometimes heavily) marked with black or brown streaks, blotches, or spots (Figure 1). Sora eggs are incubated by both sexes for 16–20 days; incubation begins any time from the laying of the first egg to the ninth egg but at least three days before the last egg is laid, and hatching occurs asynchronously. Redwing eggs are incubated by the female only, usually beginning after the penultimate egg is laid, and eggs hatch asynchronously within 11–13 days after the onset of incubation. Newly hatched Sora chicks are precocial but semi-nidifugous, i.e., chicks may leave the nest within 24 h of hatching but generally do not leave the nest until 3–4 days after hatching unless disturbed. Redwing nestlings are altricial: chicks depart the nest 10–12 days after hatching.

Despite these differences, an observation of a female redwing accepting a Sora egg is not surprising. Although differences in egg appearance (i.e., shape, size, maculation, ultraviolet reflectance, brightness, colour) are used by many avian species to identify and remove heterospecific eggs from their nests (Rothstein 1974; Jackson 1998; Croston and Hauber 2014), previous experiments have shown that redwings invariably accept foreign and artificial eggs (Rothstein 1975; Roskaft *et al.* 1990), although they are capable of removing them (Ortega and Cruz 1988). In the northern Great Plains, redwing nests are moderately to heavily parasitized by Brown-headed Cowbirds, and the species is considered a preferred cowbird host in this region (Igl and Johnson 2007).

It is much easier to understand how a female redwing would accept a Sora egg in its nest than to explain why a female Sora would lay its egg in an elevated and dissimilar nest of a seemingly unsuitable non-rallid host. Several hypotheses have been proposed to explain parasitic egg-laying by conspecific parasites (Lyon 1993) and may be important to understanding these rare cases of heterospecific parasitism in the Sora. These hypotheses include: (1) floater females without nests or territories of their own may depend entirely on nesting females to raise their offspring; (2) nesting females who lose their nests during laying and have eggs ready to lay but no nest to lay them in may be forced to lay their eggs in nests of other females; (3) nesting females may delay their own nest initiation because of some constraint (e.g., condition of their mate or territory) and lay parasitically until conditions improve; or (4) nesting females can increase their immediate or lifetime reproduction and spread the risk of predation by laying surplus eggs in the nests of other females (Lyon 1993). These hypotheses overlap with the motivations proposed by Wiens (1971) to explain egg dumping, i.e., incidental laying of eggs in other species' nests. These

hypotheses also reflect Sealy's (2015) interpretation of egg laying in nests of inappropriate, non-passerine hosts by Brown-headed Cowbirds.

Each of these hypotheses predicts a different pattern to the distribution and timing of parasitic or inappropriate egg laying. For Soras at this study site, observers did not record information on abundance, the presence of floater females, nest fate, constraints, or lifetime reproduction, and, thus, we lack a full understanding of these key hypotheses. However, high densities of Soras in these experimental ponds and competition for nest sites may have contributed to these rare cases of parasitism. The experimental ponds supported one of the highest nest densities of Soras reported in the literature: 14 and 12 nests/ha of wetland surface area in 2009 and 2010, respectively. Local density estimates for Sora pairs elsewhere range from 0.1 pairs/ha in central North Dakota (Kantrud and Stewart 1984) to 2.5 pairs/ha in northwest Iowa (Griese *et al.* 1980). In some waterfowl and colonial waterbird species, the probability of being parasitized by a conspecific increases with nest density (Rohwer and Freeman 1989; Petrie and Moller 1991; Fournier 2000). Competition for or limited availability of nest sites has been implicated in some parasitic laying by waterfowl (Sayler 1992).

Finally, although it is unlikely that redwings would provide the type of parental care needed to raise precocial Sora young successfully, these observations represent the first report of successful hatching of a Sora egg found in a redwing nest. In one of the parasitized redwing nests in this study, the Sora egg hatched six or seven days after the redwing eggs hatched. This is within the known incubation period for Sora (Melvin and Gibbs 2012). Previous experiments have shown that redwings are capable of prolonged incubation up to 13–14 days beyond their typical incubation period (Holcomb 1970, 1974). Other studies have reported icterid species hatching non-passerine eggs several days after the host eggs hatched. In Post and Seals' (1989) report of a Common Moorhen egg in a Boat-tailed Grackle nest, the moorhen egg hatched 10 days after the last grackle egg, and the moorhen chick jumped from the nest and swam away. Yasukawa (2010) reported a case of a female redwing hatching and feeding a Yellow-billed Cuckoo (*Coccyzus americanus*) chick, despite a 3- to 4-day delay in hatching of the cuckoo egg compared with the host eggs. Craik (2010) argued that, although mixed clutches of altricial and precocial eggs might seem incompatible, it is imprudent to assume that all unsuitable combinations are doomed to fail. Had the Sora chick survived in the above nest, it could have parasitized parental care from neighbouring conspecifics or its own biological parents (*sensu* Davies 2000). Conspecific parasitism is not particularly well studied in Sora, and the observations of heterospecific parasitism reported here raise additional questions and highlight the need for more studies regarding the factors influencing brood parasitism in this species.

Acknowledgements

I thank A. L. Igl, K. L. McLean, P. J. Pietz, and J. C. Slagter for field assistance, and Pamela J. Pietz and two anonymous reviewers for comments on an earlier version of this manuscript.

Literature Cited

- Allen, A. A. 1939. *The Golden Plover and Other Birds*. Comstock Publishing, Ithaca, New York, USA.
- Arnold, T. W. 1987. Conspecific egg discrimination in American Coots. *Condor* 89: 675–676. <https://doi.org/10.2307/1368662>
- Craik, J. C. A. 2010. Mixed clutches at seabird colonies in west Scotland 1996–2009. *Seabird* 23: 41–52.
- Croston, R., and M. E. Hauber. 2014. Spectral tuning and perceptual differences do not explain the rejection of brood parasitic eggs by American Robins (*Turdus migratorius*). *Behavioral Ecology and Sociobiology* 68: 351–362. <https://doi.org/10.1007/s00265-013-1649-8>
- Davies, N. B. 2000. *Cuckoos, Cowbirds and Other Cheats*. T. and A. D. Poyser, London, United Kingdom.
- Fournier, M. A. 2000. Incidents of mixed clutches among scaup and Ring-billed Gulls. *Waterbirds* 23: 114–116.
- Gibbons, D. W. 1986. Brood parasitism and cooperative nesting in the Moorhen, *Gallinula chloropus*. *Behavioral Ecology and Sociobiology* 19: 221–232.
- Gollop, B. 1949. Sora's egg in red-wing's nest. *Canadian Field-Naturalist* 63: 42. Accessed 20 March 2018. <https://www.biodiversitylibrary.org/item/89254#page/52/mode/1up>.
- Griese, H. J., R. A. Ryder, and C. E. Braun. 1980. Spatial and temporal distribution of rails in Colorado. *Wilson Bulletin* 92: 96–102.
- Holcomb, L. C. 1970. Prolonged incubation behaviour of the Red-winged Blackbird incubating several eggs sizes. *Behaviour* 36: 74–83. <https://doi.org/10.1163/156853970X00051>
- Holcomb, L. C. 1974. Incubation constancy in the Red-winged Blackbird. *Wilson Bulletin* 86: 450–460.
- Igl, L. D., and D. H. Johnson. 2007. Brown-headed Cowbird, *Molothrus ater*, parasitism and abundance in the northern Great Plains. *Canadian Field-Naturalist* 121: 239–255. <https://doi.org/10.22621/cfn.v121i3.471>
- Jackson, W. M. 1998. Egg discrimination and egg-color variability in the Northern Masked Weaver. Pages 407–416 in *Parasitic Birds and Their Hosts: Studies in Coevolution*. Edited by S. I. Rothstein and S. K. Robinson. Oxford University Press, New York, New York, USA.
- Jamieson, I. G., S. B. McRae, M. Trewby, and R. E. Simons. 2000. High rates of conspecific brood parasitism and egg rejection in coots and moorhens in ephemeral wetlands in Namibia. *Auk* 117: 250–255. [https://doi.org/10.1642/0004-8038\(2000\)117\[0250:HROCBP\]2.0.CO;2](https://doi.org/10.1642/0004-8038(2000)117[0250:HROCBP]2.0.CO;2)
- Kantrud, H. A., and R. E. Stewart. 1984. Ecological distribution and crude density of breeding birds on prairie wetlands. *Journal of Wildlife Management* 48: 426–437. <https://doi.org/10.2307/3801174>
- Lokemoen, J. T., and R. R. Koford. 1996. Using candlers to determine the incubation stage of passerine eggs. *Journal of Field Ornithology* 67: 660–668.
- Lyon, B. E. 1993. Conspecific brood parasitism as a flexible female reproductive tactic in American Coots. *Animal Behaviour* 46: 911–928. <https://doi.org/10.1006/anbe.1993.1273>

- Lyon, B. E.** 2003. Egg recognition and counting reduce costs of avian conspecific brood parasitism. *Nature* 422: 495–499. <https://doi.org/10.1038/nature01505>
- Lyon, B. E., and J. McA. Eadie.** 2004. An obligate brood parasite trapped in the intraspecific arms race of its hosts. *Nature* 432: 390–393. <https://doi.org/10.1038/nature03036>
- Lyon, B. E., and J. McA. Eadie.** 2008. Conspecific brood parasitism in birds: a life-history perspective. *Annual Review of Ecology, Evolution, and Systematics* 39: 343–363. <https://doi.org/10.1146/annurev.ecolsys.39.110707.173354>
- McRae, S. B.** 1996. Brood parasitism in the moorhen: brief encounters between parasites and hosts and the significance of an evening laying hour. *Journal of Avian Biology* 27: 311–320. <https://doi.org/10.2307/3677262>
- Melvin, S. M., and J. P. Gibbs.** 2012. Sora (*Porzana carolina*). In *The Birds of North America*. Edited by P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. <https://doi.org/10.2173/bna.250>
- Miller, R. F.** 1928. Virginia Rail lays in Sora's nest. *Oologist* 45: 132.
- Ortega, C. P., and A. Cruz.** 1988. Mechanisms of egg acceptance by marsh-dwelling blackbirds. *Condor* 90: 349–358. <https://doi.org/10.2307/1368563>
- Peer, B. D.** 2006. American Coot parasitism on Least Bitterns. *Wilson Journal of Ornithology* 118: 415–418. <https://doi.org/10.1676/05-096.1>
- Petrie, M., and A. P. Møller.** 1991. Laying eggs in others' nests: intraspecific brood parasitism in birds. *Trends in Ecology & Evolution* 6: 315–320. [https://doi.org/10.1016/0169-5347\(91\)90038-Y](https://doi.org/10.1016/0169-5347(91)90038-Y)
- Post, W., and C. Seals.** 1989. Common Moorhen parasitizes a Boat-tailed Grackle nest. *Wilson Bulletin* 101: 508–509.
- Post, W., and C. A. Seals.** 2000. Breeding biology of the Common Moorhen in an impounded cattail marsh. *Journal of Field Ornithology* 71: 437–442. <https://doi.org/10.1648/0273-8570-71.3.437>
- Rohwer, F. C., and S. Freeman.** 1989. The distribution of conspecific nest parasitism in birds. *Canadian Journal of Zoology* 67: 239–253. <https://doi.org/10.1139/z89-035>
- Røskoft, E., G. H. Orians, and L. D. Beletsky.** 1990. Why do Red-winged Blackbirds accept eggs of Brown-headed Cowbirds? *Evolutionary Ecology* 4: 35–42. <https://doi.org/10.1007/BF02270713>
- Rothstein, S. I.** 1974. Mechanisms of avian egg recognition: possible learned and innate factors. *Auk* 91: 796–807. <https://doi.org/10.2307/4084731>
- Rothstein, S. I.** 1975. An experimental and teleonomic investigation of avian brood parasitism. *Condor* 77: 250–271. <https://doi.org/10.2307/1366221>
- Samraoui, F., and B. Samraoui.** 2007. The reproductive ecology of the Common Coot (*Fulica atra*) in the Hauts Plateaux, Northeast Algeria. *Waterbirds* 30: 133–139. [https://doi.org/10.1675/1524-4695\(2007\)030\[0133:TREOTC\]2.0.CO;2](https://doi.org/10.1675/1524-4695(2007)030[0133:TREOTC]2.0.CO;2)
- Sayler, R. D.** 1992. Ecology and evolution of brood parasitism in waterfowl. Pages 290–322 in *Ecology and Management of Breeding Waterfowl*. Edited by B. D. J. Batt, A. D. Afton, M. G. Anderson, D. D. Ankeny, D. H. Johnson, J. A. Kadlec, and G. L. Krapu. University of Minnesota Press, Minneapolis, Minnesota, USA.
- Sealy, S. G.** 2015. Egg laying in inappropriate nests by the Brown-headed Cowbird (*Molothrus ater*): acts of parasitism or emergency egg dumping? *Canadian Field-Naturalist* 129: 60–69. <https://doi.org/10.22621/cfn.v129i1.1668>
- Sorenson, M. D.** 1995. Evidence of conspecific nest parasitism and egg discrimination in the Sora. *Condor* 97: 819–821. <https://doi.org/10.2307/1369192>
- Swales, B. H.** 1896. A full set of rail's. *Nidologist* 3: 142.
- Tanner, W. D., and G. O. Hendrickson.** 1954. Ecology of the Virginia Rail in Clay County, Iowa. *Iowa Bird Life* 24: 65–70.
- Ueda, K., and Y. Narui.** 2004. A new breeding tactic of the Common Moorhen: interspecific brood parasitism of bittern nests. *Ornithological Science* 3: 163–166. <https://doi.org/10.2326/osj.3.163>
- Ueda, K., H. Uchida, and T. Matsuda.** 1993. Egg-dumping by the Moorhen, *Gallinula chloropus*, in Japan. *Japanese Journal of Ornithology* 42: 21–25. <https://doi.org/10.3838/jjo.42.21>
- Walkinshaw, L. H.** 1940. Summer life of the Sora rail. *Auk* 57: 153–168. <https://doi.org/10.2307/4078743>
- Walkinshaw, L. H.** 1957. Incubation period of the Sora rail. *Auk* 74: 496. <https://doi.org/10.2307/4081750>
- Wiens, J. A.** 1971. "Egg-dumping" by the Grasshopper Sparrow in a Savannah Sparrow nest. *Auk* 88: 185–186. <https://doi.org/10.2307/4083990>
- Weller, M. W.** 1956. A simple field candler for waterfowl eggs. *Journal of Wildlife Management* 20: 111–113. <https://doi.org/10.2307/3797414>
- Yasukawa, K.** 2010. Yellow-billed Cuckoo hatched and fed by a Red-winged Blackbird. *Wilson Journal of Ornithology* 122: 402–405. <https://doi.org/10.1676/09-132.1>
- Yasukawa, K., and W. A. Searcy.** 1995. Red-winged Blackbird (*Agelaius phoeniceus*). In *The Birds of North America*. Edited by P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. <https://doi.org/10.2173/bna.184>
- Yom-Tov, Y.** 2001. An updated list and some comments on the occurrence of intraspecific nest parasitism in birds. *Ibis* 143: 133–143. <https://doi.org/10.1111/j.1474-919X.2001.tb04177.x>

Received 20 December 2016

Accepted 27 September 2017

Changes to the Population Status of Horned Grebes (*Podiceps auritus*) and Red-necked Grebes (*Podiceps grisegena*) in Southwestern Manitoba, Canada

GORD HAMMELL

P.O. Box 37, Erickson, Manitoba R0J 0P0 Canada; email: gmhammell@gmail.com

Hammell, Gord. 2017. Changes to the population status of Horned Grebes (*Podiceps auritus*) and Red-necked Grebes (*Podiceps grisegena*) in southwestern Manitoba, Canada. *Canadian Field-Naturalist* 131(4): 317–324. <https://doi.org/10.22621/cfn.v131i4.2069>

Continental trend data for North America suggest that Horned Grebe (*Podiceps auritus*) breeding populations are declining and Red-necked Grebe (*P. grisegena*) populations are increasing. However, data reliability is low due to lack of survey routes in the northern boreal and taiga ecozones, areas encompassing much of the breeding range of both species. Locally in the southern Manitoba prairie ecozone, reliability of long-term trend data is also considered low and these data suggest that Horned Grebe populations are declining faster than the continental trend and that Red-necked Grebe populations are increasing rapidly. The lack of current quantitative information on population densities of these two species in southern Manitoba prompted me to compare 1970s historical data from two sites to recent data collected at the same locations in 2008–2016. I surveyed 42 (1970–1972) and 38 (2008–2016), and 144 (2009–2015) Class III–V wetlands at Erickson and Minnedosa, Manitoba, respectively. Historical Minnedosa data were available from previous field studies. At both locations, Horned Grebe breeding populations have fallen significantly, and Red-necked Grebe populations have risen significantly since the 1970s. The results of this study corroborate the Breeding Bird Survey's trend data for Horned and Red-necked Grebes in southwestern Manitoba pothole habitat.

Key Words: Horned Grebe; *Podiceps auritus*; Red-necked Grebe; *Podiceps grisegena*; Manitoba prairie-potholes; species at risk; population status

Introduction

Horned Grebes (*Podiceps auritus*) and Red-necked Grebes (*P. grisegena*) are highly-specialized waterbirds that nest over-water in or near emergent vegetation on semi-permanent or permanent ponds. Horned Grebes prefer small (less than 2 ha) open-water wetlands for nest sites in Manitoba, Saskatchewan, and North Dakota (Faaborg 1976; Sugden 1977; Ferguson and Sealy 1983) whereas the larger Red-necked Grebe usually occupy wetlands greater than 2 ha (Riske 1976 as cited in Stout and Nuechterlein 1999; De Smet 1983 as cited in Stout and Nuechterlein 1999; the current study; but see Fournier and Hines 1998). For both species, males and females are similar in appearance and difficult to distinguish in the field. They are intra- and inter-specifically territorial. Both species have Holarctic distributions and, in North America, the majority of their populations have a similar breeding range, extending from northwestern Ontario and the northwestern United States to the Northwest Territories and Alaska (Stout and Nuechterlein 1999; Stedman 2000). The Horned Grebe Western population is listed as special concern but the small (less than 15 birds), disjunct Magdalen Island population in the Gulf of St. Lawrence is listed as endangered under the *Species at Risk Act* following their 2009 assessments by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; SARA Registry 2017a,b). Red-necked Grebe was last assessed by COSEWIC in 1982 as 'not at risk' (SARA Registry

2017c). Although the reproduction and behaviour of the species have been studied extensively in Eurasia and North America (Stout and Nuechterlein 1999; Stedman 2000; Klatt 2003; Nuechterlein *et al.* 2003; Klatt *et al.* 2004; Kuczynski *et al.* 2012), accurate information on population trends for breeding and wintering populations in North America is still lacking (Stout and Nuechterlein 1999; Stedman 2000; COSEWIC 2009). Breeding Bird Survey (BBS) data suggest continental declines for Horned Grebe and increases for Red-necked Grebe (yearly % change 1966–2015: Horned Grebe -0.47 , Red-necked Grebe $+0.65$; Sauer *et al.* 2017). But BBS data have limited value, as much of the breeding range of both species lies in the northern boreal and taiga ecozones, areas with few BBS survey routes. Thus, potential data are missing and results are biased towards southern prairie-parkland populations (COSEWIC 2009).

Locally in the parklands of southern Manitoba, the reliability of BBS data for Horned Grebe and Red-necked Grebe are considered low due to small sample sizes but the data suggest that Horned Grebe populations are decreasing and Red-necked Grebe populations are increasing (Manitoba Prairie-potholes long-term trend 1970–2015 yearly % change: Horned Grebe -2.94 ; Red-necked Grebe $+10.7$; Environment and Climate Change Canada 2017). No corroborative, multi-year studies of reproduction have been conducted in this area in over 30 years (Ferguson and Sealy 1983;

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalists' Club.

De Smet 1987). Intensive monitoring at a local scale can provide additional trend information, and in conjunction with landscape data (e.g., BBS), may allow more accurate decisions regarding the need for possible intervention (e.g., small wetland construction for Horned Grebe; Kuczynski *et al.* 2012). Accordingly, personal anecdotal evidence suggesting changes in grebe populations in southwestern Manitoba and the lack of current quantitative information prompted me to examine the extent of any change. I took advantage of historical data from two locations in southwestern Manitoba (Erickson and Minnedosa) and compared these data to those collected in 2008–2016 at the same locations.

Study Area

The study areas are in the parkland pothole region of southwestern Manitoba (Figure 1). The topography

of the region is rolling hills with numerous ponds and lakes; the uplands are a mixture of cereal and oilseed crops, hay, pasture, and native woodland (mainly poplars, *Populus* spp.). The Erickson study area (50.470351°N, 99.895847°W) consists of a 6.8 km² area established by the author in 1970, and contained 12 seasonal (Class III: 0.4 ± 0.3 ha, 0.1–1.3 [average ± SD, range]), seven semi-permanent (Class IV: 0.5 ± 0.3 ha, 0.2–0.9), and 23 permanent (Class V: 2.0 ± 2.3 ha, 0.1–8.7 [18 natural, five constructed dugouts]) wetlands during 1970–1972 (~ 6 wetlands/km²; classification according to Stewart and Kantrud [1971]). In 2008–2016, two Class III and two small Class V wetlands (dugouts) had been lost due to draining or filling. The 7.1 km² Minnedosa study area (50.125001°N, 99.844663°W), established in 2009 by the author, is about 27 km south of the Erickson site and is a 17.7 km × 0.4 km roadside transect (0.2 km either side) and

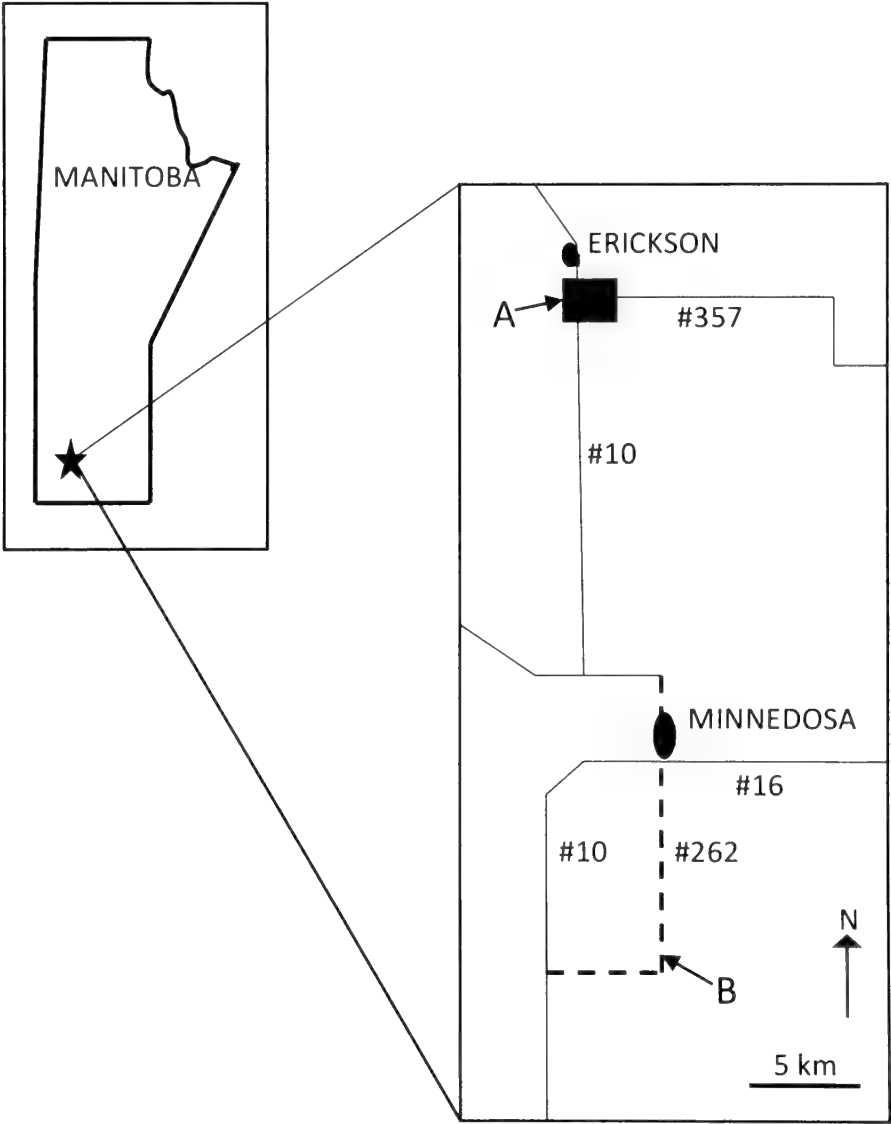


FIGURE 1. Location of Red-necked Grebe (*Podiceps grisegena*) and Horned Grebe (*Podiceps auritus*) study areas in south-west Manitoba, Canada: 6.8 km² Erickson site (black square A: 1970–1972, 2008–2016), and 7.1 km² Minnedosa transect (dashed line B: 2009–2015).

contained ten Class III (0.1 ± 0.07 ha, $0.02 - 0.22$), 118 Class IV (0.9 ± 0.9 ha, $0.03 - 4.0$), and 16 Class V (1.6 ± 1.1 ha, $0.06 - 3.6$ [nine natural; seven {five flooded; dugouts}] wetlands (~ 20 wetlands/km²). The latter study site is part of a larger site intensively studied for Horned Grebe in 1974–1975 (Ferguson 1977). Using 1964 and 2011 aerial photos of the Minnedosa transect (Aerial Data Survey Base, Natural Resources Canada and Google Earth, respectively), I estimated about a 2% loss (four Class IV lost, one dugout added) of Class IV and V wetlands between 1964 and 2011. Because Horned Grebes and Red-necked Grebes occupy Class IV and V wetlands almost exclusively during the breeding season, both study sites have experienced little grebe habitat loss between the 1970s and 2000s.

At Erickson, wetland water levels were high in the springs of 1970–1972 and in all years in the 2000s except 2012 (unpublished data). At Minnedosa, wetlands were wet in spring 1974–1975 (Ferguson 1977) and in all years 2009–2015 except 2012, and 2013 when the north section of the transect was dry (personal observation). Mean total yearly precipitation (*Precip*), 1981–2010, for Wasagaming, Manitoba ~ 21 km north of the Erickson site and for Brandon, Manitoba ~ 23 km south of the Minnedosa transect was 488 mm and 474 mm, respectively (Environment Canada Historical Climate Data 2016). Both early and recent study period *Precip* was greater than long-term averages (Erickson [Wasagaming] *Precip* 1970–1972 and 2009–2015 was 514 mm and 592 mm, respectively; Minnedosa [Brandon] *Precip* 1974–1975 and 2009–2015 was 529 mm and 506 mm, respectively). At Erickson, most wetlands were wetter (and some were larger) during 2008–2016 than during 1970–1972. Good wetland conditions are necessary to attract grebes to settle on territories (Stout and Nuechterlein 1999; Stedman 2000).

Methods

As both species require wetlands with open water for breeding (Stout and Nuechterlein 1999; Stedman 2000), I restricted my observations to ponds equal to or greater than Class III (some Class III wetlands have open water, cover type 3 and 4; Stewart and Kantrud 1971). Both species are thought to attain full nuptial plumage at 1-year old, but some adults may not breed until greater than 1-year old (Stout and Nuechterlein 1999; Stedman 2000). The number of non-breeding Red-necked Grebes and Horned Grebes observed on the breeding ponds is assumed to be low (Riske 1976 as cited in Stout and Nuechterlein 1999; Fjelds  1973 as cited in Stedman 2000). Thus, I assumed that all birds observed represented members of breeding pairs. At Erickson, one or two observers walked a fixed route at approximately weekly intervals from early May to late June 1970–1972 and from mid-May to mid-June 2008–2016. All wetlands were scanned with binoculars and spotting scopes from one or more elevated locations between 0600 and 1400 hours. At the Minnedosa

transect, late May was the optimal census period to observe the greatest number of Horned Grebes when only one survey was conducted (Arnold 1994). One observer conducted one late-May survey beginning at ~ 0600 hours (1100 hours in 2009) at the southwest end and proceeded east, then north (6–10 hrs to complete) in all years except 2014 (June 5th). Each wetland within 200 m of the road was approached by vehicle or on foot and quickly scanned in its entirety then rescanned for 1 min or more, according to Arnold (1994). If the transect line bisected a large wetland ($n = 3$), I included only those grebes in the analysis observed within the transect. Horned Grebes were recorded as single birds or pairs (two birds in close proximity, not displaying aggressive behaviour) and a single bird on a wetland was assumed to represent a pair on that wetland (but see below for differing analysis of Minnedosa Horned Grebe data). Rarely does more than one pair of Horned Grebe occupy a given wetland at the Minnedosa site (Ferguson 1977) but at Erickson, larger wetlands allow for more pairs, and greater scrutiny was necessary. Similarly, for Red-necked Grebes, territory establishment and initial egg-laying occurs in May in Manitoba (egg-laying peaked in late May; De Smet 1987), and counts taken during mid to late May would best represent the breeding population (Stout and Nuechterlein 1999; personal observation). Red-necked Grebes were recorded as pairs or single birds (representing a probable pair). Many pairs could occupy larger lakes (especially at Erickson after 1999) so long observation times (to 0.5 hr) were necessary to estimate numbers. Repeated total counts from several elevated viewpoints combined with field maps of bird locations (to determine territories) aided estimation. At Minnedosa, the relatively smaller Class IV and V wetlands generally precluded the occurrence of more than one pair of Red-necked Grebe at a site.

For 2009 and 2010, time constraints allowed only a partial census of the Minnedosa transect (40% of total Class III wetlands, 66% of Class IV and V combined). Consequently, to estimate the number of pairs on the entire transect for those years, I developed a correction factor using 2011–2015 data (see method in Hammell 2016). This analysis indicated that the number of Horned Grebe and Red-necked Grebe pairs recorded in 2009 and 2010 on the partially surveyed transect represented 80% and 89%, respectively, of total pairs that would have been seen on the entire transect and this adjustment was applied to the 2009 and 2010 raw data.

Horned and Red-necked Grebes differ in their willingness to remain visible at disturbance. At the sight of the observer, Horned Grebes generally dive underwater, sometimes swimming into emergent vegetation to hide (Arnold 1994; personal observation). At Erickson, repeated wetland visits over the season increased the accuracy of Horned Grebe pair estimates and data presented for this site are considered reasonable estimates. However, at Minnedosa, because only one sur-

vey was conducted, lowered observability necessitated the application of a correction factor using my total adult bird numbers (i.e., estimating density using single birds and assumed pairs as described above for Erickson might bias breeding pair results downward for Minnedosa). Arnold (1994) estimated Horned Grebe visual detection of total adults for a single survey at Minnedosa as 62% based on known nesting populations determined from repeated nest searches. Therefore, an estimate of the number of initial nests (and the presumed breeding population) can be calculated using visible adults and the correction factor (Horned Grebe adults recorded/ $0.62 =$ estimate of total adults/ $2 =$ number of initial nests or breeding pairs; T. Arnold, personal communication). In contrast, Red-necked Grebes generally remain in open water on the surface. If they are not obvious at arrival, usually one or both pair members swim out from emergent vegetative cover after a short wait (personal observation). Therefore, recorded pair estimates are considered reasonably accurate, and no correction factor has been applied to Red-necked Grebe raw numbers.

Recent estimates of pairs/km² after 1999 were compared to estimates from my historical data at Erickson, and for Minnedosa, to estimates calculated from data in Ferguson (1977) and Stoudt (1982). Ferguson (1977: 36) found 34 and 36 initial nests in 1974 and 1975, respectively, on his 34.4 km² (29.2 km² roadside transect + 5.2 km² adjacent block) study area. I used these data to calculate Horned Grebe breeding pair densities for those years. Red-necked Grebes were not included in species lists nor discussion for two water-bird studies at Minnedosa during 1961–1972 (Stoudt 1982) and 1974–1975 (Ferguson 1977). So, I assumed

them not to be present or in very low densities prior to 1980 and used the number, 0 pairs / km², to represent density for that period. Densities were still very low in the mid-1980s (T. Arnold, personal communication; K. De Smet, personal communication). I compared historical and recent data with non-parametric Wilcoxon rank-sum test via *t*-test on rank transformed data (data analysis using Microsoft Excel, Redmond, Washington, USA), and considered differences significant at $P \leq 0.05$, because the distribution of variables was unknown and sample sizes were small. Means are expressed as \pm SD, range (McDonald 2014). Areas were determined by dot grid overlay or Acme Planimeter (<http://acme.com/planimeter>).

Results

Horned Grebes

At Erickson, Horned Grebes used some of the same wetlands in the 2000s as in the 1970s (1970s: 2.8 ± 2.8 ha, 0.6–8.7, $n = 14$; 2000s: 6.3 ha, 1.2–11.3, $n = 2$). In 2016, one pair occupied a large Class V wetland (11.3 ha) with four pairs of Red-necked Grebes. At Minnedosa, Horned Grebes in the 2000s used semi-permanent and permanent wetlands similar in size to those used in the 1970s (1974–1975: 1.2 ± 1.3 ha, 0.1–8.4, $n = 65$; Ferguson and Sealy 1983; 2009–2015: 1.3 ± 0.9 ha, 0.2–3.1, $n = 10$) and were not recorded on a wetland occupied by a Red-necked Grebe.

Horned Grebe pairs/km² changed significantly from historical to recent times (Table 1). At Erickson, Horned Grebe density fell from 1.8 pairs/km² in 1970 (mean = 1.3, 1970–1972) to 0 pairs/km² for most years in the 2000s (mean = 0.0; $t = -4.37$, $P = 0.001$). Similarly, at Minnedosa, Horned Grebe density fell from 1.0 pairs/

TABLE 1. Estimated breeding pairs per km² (total pairs in parentheses) of Horned Grebes (*Podiceps auritus*; HOGR) and Red-necked Grebes (*Podiceps grisegena*; RNGR), Erickson and Minnedosa, Manitoba study sites. Period-specific estimates: Hammell (1970–1972), Ferguson (1974–1975), Stoudt (1961–1972), and Hammell (2008–2016).

Year	Study Site			
	Erickson (6.8 km ²)		Minnedosa (7.1 km ²)	
	HOGR	RNGR	HOGR	RNGR
1970	1.8 (12.0)	0.0 (0.0)	no data	0.0 (0.0)
1971	1.2 (8.0)	0.1 (1.0)	no data	0.0 (0.0)
1972	0.9 (6.0)	0.0 (0.0)	no data	0.0 (0.0)
Mean	1.3 (8.7)	0.0 (0.3)	no data	0.0 (0.0)
1974	no data	no data	1.0 (34.0)	0.0 (0.0)
1975	no data	no data	1.0 (36.0)	0.0 (0.0)
Mean	no data	no data	1.0 (35.0)	0.0 (0.0)
2008	0.1 (1.0)	2.6 (18.0)	no data	no data
2009	0.1 (1.0)	2.5 (17.0)	0.4 (3.0)	1.0 (7.0)
2010	0.0 (0.0)	2.6 (18.0)	0.6 (4.0)	2.0 (14.0)
2011	0.0 (0.0)	2.8 (19.0)	0.0 (0.0)	2.7 (19.0)
2012	0.0 (0.0)	2.6 (18.0)	0.4 (3.0)	2.8 (20.0)
2013	0.0 (0.0)	2.6 (18.0)	0.0 (0.0)	2.2 (16.0)
2014	0.0 (0.0)	3.1 (21.0)	0.4 (3.0)	2.5 (18.0)
2015	0.0 (0.0)	2.9 (20.0)	0.1 (1.0)	2.5 (18.0)
2016	0.1 (1.0)	2.9 (20.0)	no data	no data
Mean	0.0 (0.3)	2.7 (19.0)	0.3 (2.0)	2.2 (16.0)

km² in both 1974 and 1975 (mean = 1.0) to a range of 0 to 0.6 pairs/km² during the 2000s (mean = 0.3; $t = -2.94$, $P = 0.021$).

Red-necked Grebes

At Erickson, Red-necked Grebes occupied natural Class V (or former Class IV adjacent to and included in Class V wetlands due to flooded conditions) wetlands exclusively and consistently (5.1 ± 3.4 ha, $0.9 - 11.3$, $n = 11$). Eight of the 11 (73%) wetlands contained pairs all nine years of the study and total pair count on the study area was similar every year (Table 1). At Minnedosa, of the 35 wetlands (34 natural, one flooded dugout) with a recorded pair in 2009–2015 (2.1 ± 0.9 ha, $0.5 - 4.0$, $n = 35$), Red-necked Grebes occupied 26 Class IV (74%) and nine Class V (26%) wetlands but were less consistent than at Erickson. None of 35 wetlands were occupied all seven years but 16 of 35 (46%) were occupied equal to or greater than four years. Total pair count was similar each year after 2010.

Red-necked Grebe pairs/km² also changed significantly from historical to recent times (Table 1). At Erickson, Red-necked Grebe density increased dramatically from very low values of 0.1 or 0 pairs/km² in the 1970s (mean = 0.0, 1970–1972) to values of greater than 2 pairs/km² in all years in the 2000s (mean = 2.7; $t = 3.59$, $P = 0.005$). Similarly, at Minnedosa, Red-necked Grebe density increased from 0 pairs/km² during 1974 and 1975 to values of greater than 2 pairs/km² in all but one year (1.0 in 2009) in the 2000s (mean = 2.2; $t = 2.87$, $P = 0.028$).

Discussion

The results of this study corroborate the BBS trend data for Horned Grebes and Red-necked Grebes in southwestern Manitoba pothole habitat. At Erickson and Minnedosa sites in the 2000s, the density of Horned Grebe breeding pairs has fallen to less than one third of the mean level in the 1970s and the density of Red-necked Grebe breeding pairs has risen dramatically from nil or essentially nil in the 1970s to densities in the 2000s of greater than or equal to 2.0 pairs/km². Red-necked Grebes nest in colonial groups in some areas (Nuechterlein *et al.* 2003) but not on my study sites, and for solitary-nesting pairs, my Red-necked Grebe densities are higher than any reported in North America by Stout and Nuechterlein (1999). Although sample sizes (i.e., number of years) were small in the early period, pair density differences were statistically significant. Lack of breeding Horned Grebe pairs at the Erickson site in 2010–2015 does not suggest absence of breeding in the greater Erickson area during those years but may be the result of the small size of the study area. Horned Grebes were indeed noted on a few lakes just outside the Erickson study area but at densities incomparable to the past because of the lack of local historical data. In a broader Canadian context, BBS trend data for Saskatchewan pothole habitat shows a large positive change for Red-necked Grebes and a small positive trend

for Horned Grebes for 1970–2015, and negative trends for both species in Alberta potholes (Environment and Climate Change Canada 2017). The Alberta data are corroborated by a long-term study in east-central Alberta pothole habitat that also shows negative changes in numbers of breeding Horned Grebes and Red-necked Grebes in 1989–2004 (Corrigan 2007). But these declines may have been influenced by long-term drought (C. Paszkowski, personal communication).

Several potential biases could affect my results. Across southern Manitoba, wetland type and number have changed over time due to agricultural draining and filling and such change may have affected numbers of pairs settling in the recent period. However, at the Erickson and Minnedosa sites, wetland loss between the 1970s and 2000s has been minimal and most of the ponds lost have been small, temporary, and not usually used by grebes. Thus, wetland loss on my study areas was not considered to be a significant factor explaining grebe population change. Moreover, macrohabitat conditions in almost all years, across the two study periods, appeared favourable for breeding grebes (i.e., wet). Microhabitat conditions (e.g., emergent vegetation configuration and width) may have changed, but such analysis is beyond the scope of this study and was not done. However, Horned Grebes at both sites were recorded on the same size and class of wetland as in the past suggesting that habitat conditions still may be adequate for this species. At Minnedosa, differences between observers and methodologies could have confounded the comparison. I have attempted to reduce biases there by duplicating study area and observational techniques, and applying correction factors where necessary.

Suggested reasons for the continental and local declines of Horned Grebe populations include pesticide contamination, oiling on marine wintering areas, ingestion of plastics, and breeding habitat degradation; but there are no definitive answers (Stedman 2000). In southwestern Manitoba, the arrival of Raccoon (*Procyon lotor*) at Minnedosa and Erickson in the mid-1950s and 1960s, respectively (Stoudt 1982; Hammell 2011), may have had negative effects on Horned Grebe reproduction but Raccoons are significant predators of Red-necked Grebe nests as well (Ferguson and Sealy 1983; De Smet 1987). Red-necked Grebes are larger than Horned Grebes (males: red-necked 1330.9 ± 192.9 g, $n = 15$; horned range 320–515 g, $n = 13$; Stout and Nuechterlein 1999; Stedman 2000) and exhibit interspecific aggression towards most waterbirds entering their territory (Stout and Nuechterlein 1999; personal observation). Accordingly, the increase in Red-necked Grebe populations may have restricted Horned Grebe breeding pairs from preferred habitat, forcing settlement elsewhere. I have little evidence of direct aggression to Horned Grebes because the two species were rarely seen together and when they were, Horned Grebes kept their distance from Red-necked Grebes. I did how-

ever observe Red-necked Grebes continually chasing a Horned Grebe pair on one study lake in late spring; the Horned Grebe pair had left by next survey.

At Erickson, Red-necked Grebes demonstrated strong annual fidelity to wetlands, and 57% of 14 ponds with Horned Grebe pairs for at least one year (present for two or more counts) during 1970–1972 are now occupied most or every year by Red-necked Grebes (5.66 ± 3.02 ha, $2.2\text{--}9.4$, $n = 8$). At Minnedosa, 47% of 35 ponds with a recorded Red-necked Grebe pair for at least one of the years during 2009–2015 are within the Horned Grebe preferred size of less than 2 ha (1.38 ± 0.48 ha, $0.5\text{--}1.9$, $n = 17$). Red-necked Grebe wetland fidelity was lower at Minnedosa than at Erickson and may have reflected the use of smaller wetlands at Minnedosa (mean 5.1 versus 2.1 ha, respectively) which may not provide adequate resources to attract this species every year. Red-necked Grebes usually occupy wetlands greater than 2 ha in the southern part of their range (Riske 1976 as cited in Stout and Nuechterlein 1999; De Smet 1983 as cited in Stout and Nuechterlein 1999) but Fournier and Hines (1998) reported that, although median pond size used by Red-necked Grebes in Northwest Territories was 2.4 ha (3.7 ± 0.2 ha SE, $0.1\text{--}18.2$, $n = 110$), a few pairs did occupy very small wetlands when surrounded by adjacent wetlands (seven of 110 ponds used were less than 0.3 ha). Similarly, in high wetland-dense Minnedosa habitat, Red-necked Grebes are occupying small wetlands and possibly excluding Horned Grebes. Horned Grebes are never found on smaller wetlands occupied by Red-necked Grebes, but they can occur together on larger ones (greater than 11 ha; personal observation; M. Fournier, personal communication).

In addition, Pied-billed Grebes (*Podilymbus podiceps*) are territorial and very aggressive and may be increasing in southern Manitoba (Manitoba prairie-potholes long-term trend 1970–2015 yearly % change: +1.91, BBS data; Environment and Climate Change Canada 2017). Average annual Pied-billed Grebe abundance on BBS routes in southern Manitoba during 2000–2015 is almost double that from 1970–1979 (1.13 ± 0.19 versus 0.64 ± 0.07 , respectively; unpublished analysis from Environment and Climate Change Canada 2017). Although similar in size to Horned Grebes (mass: 474.0 ± 60.6 g, $321\text{--}568$, $n = 36$; Muller and Storer 1999), Pied-billed Grebes are known to replace Horned Grebes on breeding ponds and may contribute to a reduced local breeding population as well (Faaborg 1976; Osnas 2003). Horned Grebes arriving on a local pond in the spring will stay and raise a brood if not disturbed but are often attacked continually by Pied-billed Grebes; the Pied-bill Grebe pair then nests after the Horned Grebes abandon the pond (H. Proven, personnel communication).

A comparison of the number of estimated pairs of Pied-billed Grebe on the Erickson site in the 1970s and 2000s also suggests an increase in the recent period; this

increase was most notably on three smaller wetlands (0.7 ± 0.15 ha, $0.6\text{--}0.7$) not used by Red-necked Grebes that were regularly used by Horned Grebes during 1970–1972 (unpublished data). However, sample sizes are very small and Pied-billed Grebes are extremely furtive and difficult to observe on larger wetlands resulting in some unknown degree of pair underestimation. Thus, my Pied-billed Grebe data for the Erickson site has low reliability and should be viewed with caution.

Nonetheless, all of the above suggests that Horned Grebes may be facing increased competition and territorial aggression from Red-necked Grebes and Pied-billed Grebes. Reduced Horned Grebe recruitment over many years resulting from Horned Grebe exclusion from larger and smaller wetlands by Red-necked Grebes and Pied-billed Grebes, respectively, could produce low breeding pair return rates that might explain the low density of Horned Grebes at Erickson now. Obviously, other factors occurring on or off the breeding grounds may be responsible for the decline.

Reasons for the marked increase in Red-necked Grebes in southwestern Manitoba are unclear, but change in environmental contaminant uptake may be important. Red-necked Grebes, positioned near the top of the aquatic food chain, ingest large amounts of contaminants (organochlorides, mercury, and other heavy metals) that are often found in adults, eggs, and young (Stout and Nuechterlein 1999). These contaminants are thought to have caused eggshell-thinning, unviable eggs, and high mortality at hatch leading to reduced productivity (southwest Manitoba, 1980–1981; De Smet 1987; central Alberta, 1970–1976; Riske 1976 as cited in Stout and Nuechterlein 1999). Reduction in the release of these toxins into the environment began in the mid-1970s (e.g., DDT banned in 1972 in Canada; Forsyth *et al.* 1994) and Red-necked Grebe eggs collected during 1982–1986 in Manitoba and Saskatchewan, showed a slight decline in mean organochloride residues compared to those from Manitoba collected in 1981 and Wisconsin collected in 1970 (De Smet 1987; Forsyth *et al.* 1994). To my knowledge, more recent Red-necked Grebe data have not been published. Red-necked Grebes from Manitoba are thought to winter primarily along the eastern coast of North America and accumulate contaminants during this period of their life cycle (Forsyth *et al.* 1994). Recent studies of avian species that inhabit the same marine habitats as Red-necked Grebes for some or all of their yearly cycle have shown thicker eggshells (Common Murre [*Uria aalge*]), reduced contaminant levels (Northern Gannet [*Morus bassanus*], Double-crested Cormorant [*Phalacrocorax auritus*], Atlantic Puffin [*Fratercula arctica*], Leach's Storm Petrel [*Oceanodroma leucorhoa*]), and improved reproductive performance (Northern Gannet) compared to historical observations (Pearce *et al.* 1989; Rail *et al.* 2013; Pirie-Hay and Bond 2014). These results are consistent with a reduction of contaminants in the marine

environment and reduced uptake by birds, including Red-necked Grebes. If Red-necked Grebe breeding success was low due to ingested contaminants during the period prior to the 1980s, and success improved more recently due to a reduction of the contaminant load in their environment, then the resultant increase in juvenile recruitment and need for additional breeding habitat might produce the observed increases in breeding pairs noted at Erickson and Minnedosa.

In conclusion, this study indicates that a change in Horned Grebe and Red-necked Grebe breeding populations has occurred in southwestern Manitoba over the last four decades. Reasons for these observed changes are unresolved. More current data on contaminant levels in grebes in southwestern Manitoba, and changes in population and contaminant levels in other prairie-parkland areas where historical data exist should prove valuable (Riske 1976 as cited in Stout and Nuechterlein 1999; Sugden 1977; Forsyth *et al.* 1994; Corrigan 2007). For example, current contaminant levels could be compared with levels from carcasses and egg shells from museum specimens. Other priorities include the need for surveys at the provincial, national, and continental levels to determine breeding and wintering population trends (Stout and Nuechterlein 1999; Stedman 2000).

Acknowledgements

Members of my University of Guelph committee, E. D. Bailey, R. J. Brooks, D. H. Pengelly, and R. E. Walker offered guidance and advice and their assistance during my student years was much appreciated. I thank the landowners and others around Erickson and Minnedosa for their hospitality and permission to access their lands. I also thank those who provided help in the field, especially G. Curry, R. Beaver, J. Jefferson, and H. Pengelly. Funds for the 1970's study were provided by the National Research Council of Canada, Delta Waterfowl Research Station, University of Guelph, and Canadian National Sportsman's Show.

I acknowledge the recent help of Ducks Unlimited Canada staff for library support (I. Glass) and aid with data analysis (L. Armstrong). T. Arnold (University of Minnesota), K. De Smet (Government of Manitoba) and Herb Proven (Minnedosa resident), and M. Fournier (Canadian Wildlife Service) provided supportive anecdotal information for the Minnedosa area and the Yellowknife, Northwest Territory area, respectively. K. De Smet, C. Paszkowski (University of Alberta), S. Boyd (Canadian Wildlife Service), and the editorial staff at *The Canadian Field-Naturalist* provided helpful comments to improve earlier drafts of this manuscript. Most importantly, I thank Marg for her support.

Literature Cited

Arnold, T. W. 1994. A roadside transect for censusing breeding coots and grebes. *Wildlife Society Bulletin* 22: 437-443.

Corrigan, R. M. 2007. Effectiveness of nest boxes in influencing population trends for Common Goldeneye (*Bucephala clangula*) and Bufflehead (*B. albeola*) in the Buffalo Lake Moraine. M.Sc. thesis, University of Alberta, Edmonton, Alberta, Canada.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2009. COSEWIC assessment and status report on the Horned Grebe *Podiceps auritus*. Western population and Magdalen Islands population, in Canada. COSEWIC, Environment Canada, Gatineau, Quebec, Canada. Accessed 12 February 2016. http://www.sararegistry.gc.ca/virtual_sara/files/cosewic_sr_horned_grebe_0809_e.pdf.

De Smet, K. D. 1983. Breeding ecology and productivity of Red-necked Grebes in Turtle Mountain Provincial Park, Manitoba. M.Sc. thesis, University of North Dakota, Grand Forks, North Dakota, USA.

De Smet, K. D. 1987. Organochlorines, predators and reproductive success of the Red-necked Grebe in southern Manitoba. *Condor* 89: 460-467.

Environment and Climate Change Canada. 2017. North American Breeding Bird Survey - Canadian Trends Website, Data-version 2015. Environment and Climate Change Canada, Gatineau, Quebec, Canada. Accessed 10 October 2017. <http://wildlife-species.canada.ca/breeding-bird-survey-results>.

Environment Canada. 2016. Historical Climate Data. Environment Canada, Ottawa, Ontario, Canada. Accessed 24 March 2016. http://weather.gc.ca/city/pages/mb-31_metric_e.html.

Faaborg, J. 1976. Habitat selection and territorial behavior of the small grebes of North America. *Wilson Bulletin* 88: 390-399.

Ferguson, R. S. 1977. Adaptations of the Horned Grebe for breeding in prairie pothole marshes. M.Sc. thesis, University of Manitoba, Winnipeg, Manitoba, Canada.

Ferguson, R. S., and S. G. Sealy. 1983. Breeding ecology of the Horned Grebe, *Podiceps auritus*, in southwestern Manitoba. *Canadian Field-Naturalist* 97: 401-408. Accessed 25 March 2018. <https://www.biodiversitylibrary.org/item/89042#page/423/mode/1up>.

Fjelds , J. 1973. Territory and the regulation of population density and recruitment in the Horned Grebe *Podiceps auritus arcticus* Boje, 1822. *Videnskabelige Meddelelser Dansk Naturhistorisk Forening* 136: 117-189.

Forsyth, D. J., P. A. Martin, K. D. De Smet, and M. E. Riske. 1994. Organochlorine contaminants and eggshell thinning in grebes from prairie Canada. *Environmental Pollution* 85: 51-58. [https://doi.org/10.1016/0269-7491\(94\)90237-2](https://doi.org/10.1016/0269-7491(94)90237-2)

Fournier, M. A., and J. E. Hines. 1998. Breeding ecology and status of the Red-necked Grebe, *Podiceps grisegena*, in the subarctic of the Northwest Territories. *Canadian Field-Naturalist* 112: 474-480. Accessed 25 March 2018. <https://www.biodiversitylibrary.org/item/106776#page/490/mode/1up>.

Hammell, G. S. 2011. Lesser scaup and raccoons: are there links in southwestern Manitoba? *Blue Jay* 69: 54-69.

Hammell, G. S. 2016. Reproductive rates in Lesser Scaup (*Aythya affinis*) in southwestern Manitoba: another look at the data. *Canadian Field-Naturalist* 130: 110-121. <https://doi.org/10.22621/cfn.v130i2.1834>

Klatt, P. H. 2003. Territorial behavior and nesting dispersion in Red-Necked Grebes. *Waterbirds* 26: 94-99. [https://doi.org/10.1675/1524-4695\(2003\)026\[0094:TBANDI\]2.0.CO;2](https://doi.org/10.1675/1524-4695(2003)026[0094:TBANDI]2.0.CO;2)

- Klatt, P. H., G. L. Nuechterlein, and D. Buitron.** 2004. Frequency and distribution of behaviour of Red-Necked Grebes breeding colonially and in classic territories. *Behaviour* 141: 263–277. <https://doi.org/10.1163/156853904322981842>
- Kuczynski, E. C., C. A. Paszkowski, and B. A. Gingras.** 2012. Horned Grebe habitat use of constructed wetlands in Alberta, Canada. *Journal of Wildlife Management* 76: 1694–1702. <https://doi.org/10.1002/jwmg.421>
- McDonald, J. H.** 2014. *Handbook of Biological Statistics*. Third edition. Sparky House Publishing, Baltimore, Maryland, USA.
- Muller, M. J., and R. W. Storer.** 1999. Pied-billed Grebe (*Podilymbus podiceps*). In *The Birds of North America*. Edited by P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. <https://doi.org/10.2173/bna.410>
- Nuechterlein, G. L., D. Buitron, J. L. Sachs, and C. R. Hughes.** 2003. Red-Necked Grebes become semicolonial when prime nesting substrate is available. *Condor* 105: 80–94. [https://doi.org/10.1650/0010-5422\(2003\)105\[80:RNGB SW\]2.0.CO;2](https://doi.org/10.1650/0010-5422(2003)105[80:RNGB SW]2.0.CO;2)
- Osnas, E. E.** 2003. The role of competition and local habitat conditions for determining occupancy patterns in grebes. *Waterbirds* 26: 209–216. [https://doi.org/10.1675/1524-4695\(2003\)026\[0209:TROCAL\]2.0.CO;2](https://doi.org/10.1675/1524-4695(2003)026[0209:TROCAL]2.0.CO;2)
- Pearce, P. A., J. E. Elliot, D. B. Peakall, and R. J. Norstrom.** 1989. Organochlorine contaminants in eggs of seabirds in the northwest Atlantic, 1968–1984. *Environmental Pollution* 56: 217–235. [https://doi.org/10.1016/0269-7491\(89\)90039-0](https://doi.org/10.1016/0269-7491(89)90039-0)
- Pirie-Hay, D. W., and A. L. Bond.** 2014. Thickness of Common Murre (*Uria aalge*) eggshells in Atlantic Canada. *Canadian Field-Naturalist* 128: 72–76. <https://doi.org/10.22621/cfn.v128i1.1553>
- Rail, J.-F., L. Champoux, R. A. Lavoie, and G. Chapdelaine.** 2013. Monitoring of the population and contamination of the Northern Gannet in Quebec, 1966–2009. Technical Report Series Number 528. Canadian Wildlife Service (Quebec Region). Environment Canada, Ottawa, Ontario, Canada.
- Riske, M. E.** 1976. Environmental and human impacts on grebes breeding in central Alberta. Ph.D. thesis, University of Calgary, Calgary, Alberta, Canada.
- SARA (Species at Risk) Registry.** 2017a. Species profile, Horned Grebe Western population. Accessed 29 September 2017. http://www.registrelep-sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=1045.
- SARA (Species at Risk) Registry.** 2017b. Species profile, Horned Grebe Magdalen Islands population. Accessed 29 September 2017. http://www.registrelep-sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=1046.
- SARA (Species at Risk) Registry.** 2017c. Species profile, Red-necked Grebe. Accessed 29 September 2017. http://www.registrelep-sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=322.
- Sauer, J. R., D. K. Niven, J. E. Hines, D. J. Ziolkowski, Jr., K. L. Pardieck, J. E. Fallon, and W. A. Link.** 2017. The North American Breeding Bird Survey, Results and Analysis 1966–2015. Version 2.07.2017. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA. Accessed 9 October 2017. <https://www.mbr-pwrc.usgs.gov>.
- Stedman, S. J.** 2000. Horned Grebe (*Podiceps auritus*). In *The Birds of North America*. Edited by P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. <https://doi.org/10.2173/bna.505>
- Stewart, R. E., and H. A. Kantrud.** 1971. Classification of natural ponds and lakes in the glaciated prairie region. U.S. Fish and Wildlife Service Resource Publication 92. Washington, DC, USA.
- Stoudt, J. H.** 1982. Habitat use and productivity of Canvasbacks in southwestern Manitoba 1961–72. United States Fish and Wildlife Service Special Scientific Report Wildlife No. 248. Washington, DC, USA.
- Stout, B., and G. L. Nuechterlein.** 1999. Red-necked Grebe (*Podiceps grisegena*). In *The Birds of North America*. Edited by P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. <https://doi.org/10.2173/bna.465>
- Sugden, L. G.** 1977. Horned Grebe breeding habitat in Saskatchewan parklands. *Canadian Field-Naturalist* 91: 372–376. Accessed 25 March 2018. <https://www.biodiversitylibrary.org/item/89182#page/398/mode/1up>.

Received 31 March 2016

Accepted 29 September 2017

First Report of Dealfish, *Trachipterus arcticus* (Lampriformes: Trachipteridae), from Canadian Waters

CRAIG F. PURCHASE

Department of Biology, Memorial University, St. John's, Newfoundland and Labrador A1B 3X9 Canada; email: cfpurchase@mun.ca

Purchase, C. F. 2017. First report of Dealfish, *Trachipterus arcticus* (Lampriformes: Trachipteridae), from Canadian waters. Canadian Field-Naturalist 131(4): 325–327. <https://doi.org/10.22621/cfn.v131i4.1912>

In November 2014, a recently dead specimen of the meso-pelagic Dealfish, *Trachipterus arcticus*, was found on a fjord beach in northern Newfoundland. This represents the first record of the species in Canadian waters.

Key Words: Dealfish; *Trachipterus arcticus*; Newfoundland; range extension

Dealfish, *Trachipterus arcticus* (Brünnich, 1788), is a large but rarely seen meso-pelagic lampriform from the North Atlantic (Wheeler 1969) and one of ten species in the family Trachipteridae (ribbonfishes). Here, I report the first instance of this species in Canadian waters.

In November 2014, a large silver fish was noticed on the beach below a 10-m cliff on the south side of Northern Arm in the Bay of Exploits, Newfoundland, Canada (49.156061°N, 55.363428°W; Table 1). It was there at least 3–4 days (~5°C) before being retrieved by Greg Mercer and was apparently in very good condition (i.e., recently dead). The next day, it was brought to my attention, but, before pictures could be taken, birds had inflicted serious damage to it. However, enough of the animal remained (Figure 1) for a positive identification (Wheeler 1969; Palmer 1986), which was subsequently

supported by Lou Van Guelpen (curator of fishes, Atlantic Reference Centre) using photographs.

The specimen is scaleless, and the lateral line has forward-directed spines. It is long and extremely compressed, with a long dorsal fin. The pectorals are very small and the pelvic fins could not be located. Although the exact length of the animal cannot be determined, it exceeds 75 cm, and the isopropyl preserved eye is 63.6 mm in diameter. Its live appearance is illustrated in Figure 2.

Trachipterus arcticus does not appear in the records of Atlantic Fishes of Canada (Scott and Scott 1988) nor Fishes of the Gulf of Maine (Collette and Klein-MacPhee 2002). Previous sightings have been concentrated in the northeast Atlantic, from Norway and Iceland south to Madeira Island (Palmer 1986). The Global Biodiversity Information Facility (2017) indicates that

TABLE 1. Occurrences of Dealfish (*Trachipterus arcticus*) in North American waters.

Year	Month	Location	Latitude, °	Longitude, °	Source	Collection record
2014	11	Northeast Newfoundland	49.16	55.36	Dead on beach	The Rooms Provincial Museum Division*
2003	8	Atlantic coast of Florida	29.28	81.06	Dead on beach	Florida Museum of Natural History
2003	5	Southeast of Cape Cod	39.95	67.79	Research survey	Museum of Comparative Zoology, Harvard University
2003	5	Southeast of Cape Cod	39.87	67.26	Research survey	Museum of Comparative Zoology, Harvard University
2002	12	Gulf of Mexico	29.00	86.00	Tuna longliner†	Florida Museum of Natural History
2002	11	Gulf of Mexico	29.00	86.00	Captured at sea‡	Florida Museum of Natural History
1966	3	Gulf of Mexico	28.95	94.78	Unknown	Natural History Museum of Los Angeles County
1953	10	Long Island, New York	40.98	72.09	Dead on beach	American Museum of Natural History

*Provincial Museum Division, The Rooms Corporation of Newfoundland and Labrador (NFM).

†Caught using monofilament leaders at night.

‡Also captured at night.

Sources: Froese and Pauly (2017); Global Biodiversity Information Facility (2017).

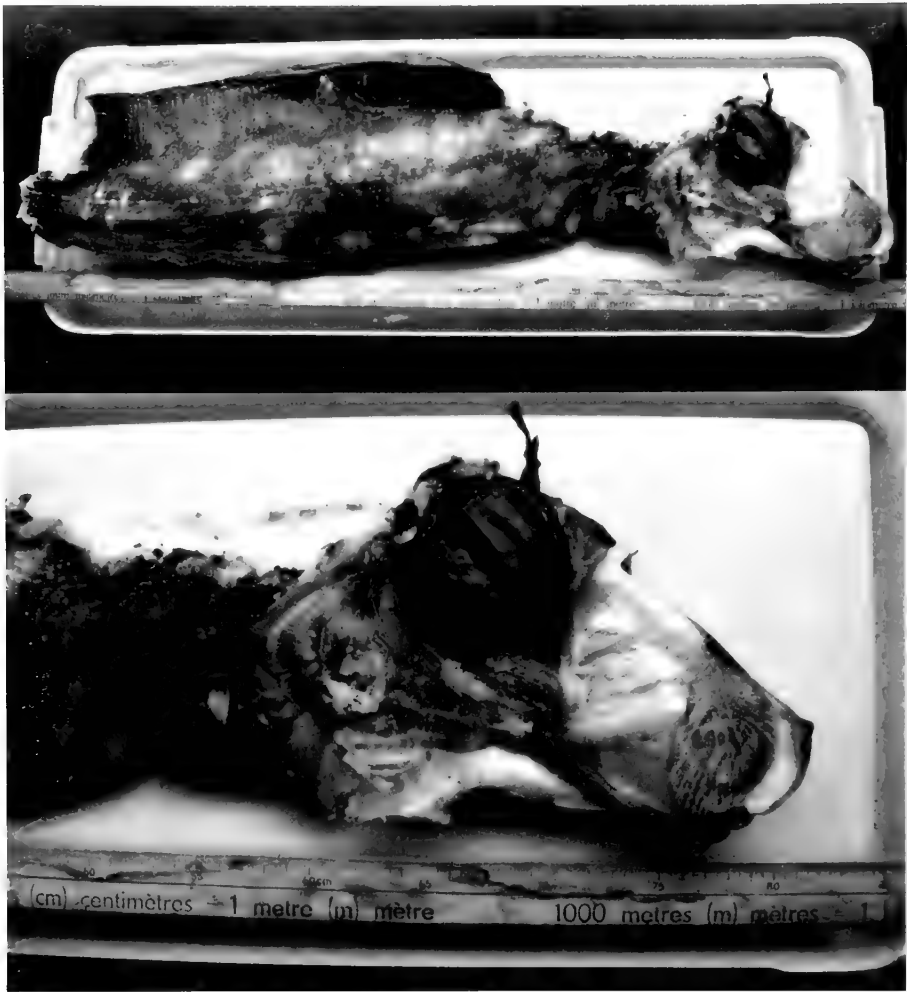


FIGURE 1. Remains of Dealfish (*Trachipterus arcticus*) found in northern Newfoundland in November 2014. The carcass was in good condition before being consumed by birds. Photos: C. Purchase.



FIGURE 2. Artist reconstruction of the Dealfish (*Trachipterus arcticus*) carcass showing missing parts (top, mouth open) and drawing of a fresh specimen of this species (bottom, mouth closed). Illustrator: Marco Graziano.

11 specimens were collected in Greenland from 1890 to 1967, but exact locations are not available. Seven specimens have been reported from United States waters (Table 1); Robins and Ray (1986) suggest these could be a separate species, although they give no reasons. Three of these were caught in the Gulf of Mexico, two off the continental slope southeast of Cape Cod, and dead specimens were found on beaches on the Atlantic coast of Florida and on eastern Long Island (New York). The specimen from Newfoundland was ~1400 km northeast of the captures offshore of Cape Cod. It has been preserved and is held by the Provincial Museum Division, of The Rooms Corporation of Newfoundland and Labrador (accession number NFM PI-118).

Acknowledgements

I thank Greg Mercer for retrieving the fish from the beach and noticing that it was something special, Jamie Dean for bringing it to my attention, and Frank Purchase for freezing it. Marco Graziano did the illustrations for Figure 2. Comments received during the review process improved an earlier version of the manuscript.

Literature Cited

- Collette, B., and G. Klein-MacPhee.** 2002. Bigelow and Schroeder's Fishes of the Gulf of Maine. Third edition. Smithsonian Institution Press, Washington, DC, USA.
- Froese, R., and D. Pauly.** 2017. *Trachipterus arcticus*: occurrence records. In Fishbase: World Wide Web electronic publication. Accessed 7 March 2017. <http://www.fishbase.org/museum/OccurrencesList.php?genus=Trachipterus&species=arcticus>.
- Global Biodiversity Information Facility.** 2017. *Trachipterus arcticus* (Brünnich, 1788). GBIF Secretariat, Copenhagen, Denmark. Accessed 7 March 2017. <http://www.gbif.org/species/2400507>.
- Palmer, G.** 1986. Trachipteridae. Pages 729–732 in *Fishes of the North-eastern Atlantic and the Mediterranean*, Volume 2. Edited by P. J. P. Whitehead, M. L. Bauchot, J. C. Hureau, J. Nielsen, and E. Tortonese. United Nations Educational, Scientific and Cultural Organization, Paris, France.
- Robins, C. R., and G. C. Ray.** 1986. A Field Guide to Atlantic Coast Fishes of North America. Houghton Mifflin Company, Boston, Massachusetts, USA.
- Scott, W. B., and M. G. Scott.** 1988. Atlantic fishes of Canada. Canadian Bulletin of Fisheries and Aquatic Sciences 219. Department of Fisheries and Oceans, Ottawa, Ontario, Canada.
- Wheeler, A.** 1969. Ribbon-fish, Deal-fish and Opah. Pages 190–192 in *The Fishes of the British Isles and North-west Europe*. Macmillan, London, United Kingdom.

Received 9 March 2017

Accepted 31 August 2017

Note

Reversed Clover, *Trifolium resupinatum* L. (Fabaceae), Confirmed in Canada

COLIN J. CHAPMAN^{1,3} and MICHAEL J. OLDHAM²

¹Atlantic Canada Conservation Data Centre, 146 Main Street, Sackville, New Brunswick E4L 1A8 Canada

²Ontario Natural Heritage Information Centre, Ministry of Natural Resources and Forestry, 300 Water Street, 2nd Floor, North Tower, Peterborough, Ontario K9J 8M5 Canada

³Corresponding author: cchap032@gmail.com

Chapman, Colin J., and Michael J. Oldham. 2017. Reversed Clover, *Trifolium resupinatum* L. (Fabaceae), confirmed in Canada. *Canadian Field-Naturalist* 131(4): 328–330. <https://doi.org/10.22621/cfn.v131i4.1866>

We report two populations of *Trifolium resupinatum* (Reversed Clover, trèfle résupiné) from southern Ontario, confirming it as established in Canada. This Eurasian and north African species was reported in the late 1800s in New Brunswick and Quebec, where it apparently did not persist. Its distribution across the United States is sporadic.

Key Words: *Trifolium resupinatum*; Reversed Clover; Persian Clover; Fabaceae; new record; Ontario; Canada

With this report of two populations in southern Ontario, *Trifolium resupinatum* L. (Reversed or Persian Clover) is confirmed as established within the flora of Canada.

Twelve species in the genus *Trifolium* are reported in the flora of Ontario (Oldham 2016). The first Ontario record of *T. resupinatum* is based on a specimen collected by Michael Oldham, K. McIntyre, J. Labrecque, R. Gould, N. Cavallin, and N. Lavoie on 25 August 2005, at the St. Clair Region Conservation Authority's McAlpine Tract in Middlesex County. *Trifolium resupinatum* was subsequently collected by Colin Chapman on 17 June 2016, in Desjardins Canal Park, in the City of Hamilton, Ontario.

Among known Ontario *Trifolium* species, *T. resupinatum* is most similar to *T. fragiferum* L. (Strawberry

Clover, trèfle fraisier), which is also rare in the province. It is distinguished from *T. fragiferum*, the only other Ontario species with inflated calices, by its resupinate flowers and the absence of stolons. Because of their similarly coloured flowers, there is also a superficial resemblance between *T. resupinatum* and the common *T. pratense* L. (Red Clover, trèfle rouge). However, *T. resupinatum* is distinguished from *T. pratense* by its smaller inflorescence (10–20 mm in diameter), the presence of floral bracteoles, and resupinate flowers. The resupinate flowers (Figure 1A), floral bracteoles, and inflated calices (Figure 1B) in fruit readily distinguish *T. resupinatum* from the other *Trifolium* species of Ontario (Haines 2011).

Trifolium resupinatum is an annual species native to Mediterranean Europe and northern Africa east to



FIGURE 1. Distinguishing features of Reversed Clover (*Trifolium resupinatum*): (A) resupinate corollas and (B) inflated calices in fruit. Photos: Colin Chapman.

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalists' Club.

Afghanistan and central Asia, where it occurs in fields, streambanks, roadsides, and waste places. It has been introduced elsewhere in Europe as well as in Australia, North America, tropical and southern Africa, and South America (Davis 1970; Zohary 1972; Townsend and Guest 1974; Meikle 1977; Zohary and Heller 1984).

In North America, *Trifolium resupinatum* has been used for silage, hay, pasture, and occasionally in lawn seed mixtures (Magness *et al.* 1971; Gillett and Cochran 1973). The species has a scattered distribution throughout the United States; it was first found in Louisiana in 1928 and is now locally established from Texas to New England (Magness *et al.* 1971; Haines 2011). It is not known from Michigan, adjacent to Ontario (Voss and Reznicek 2012).

Trifolium resupinatum was first reported in Canada in Saint John, Saint John County, New Brunswick, in 1879, on ballast waste “with *T. ornithopodioides* L. and a few other foreign species” (Fowler 1879). Hinds *et al.* (2000) knew of no subsequent New Brunswick records and did not expect it to have persisted in the province. With no supporting herbarium specimen known for *T. resupinatum*, its provincial status is “Reported but unconfirmed” (Stephen Clayden and Sean Blaney, personal communications).

Macoun (1883–1890) reported it from “near Quebec City”, Quebec, but again, no herbarium specimen exists. Brouillet *et al.* (2010+) list it as “excluded”, with the comment “old report, not established” for both New Brunswick and Quebec.

Magness *et al.* (1971) reported that *Trifolium resupinatum* used for agricultural purposes naturally reseeds, but does not tolerate low winter temperatures. However, the species has been shown to persist in western North Dakota, producing over 200 seedlings/m² in plots that had been seeded in the previous year (Carr *et al.* 2005). Most of the state of North Dakota is within plant hardiness zones 4a and 3b (USDA 2012). Much of Atlantic Canada and the southern portions of the remaining Canadian provinces are within plant hardiness zones equal to or warmer than North Dakota; Middlesex County is in plant hardiness zone 6b (Natural Resources Canada 2016). The warmer average annual extreme minimum temperature suggests that *T. resupinatum* is likely able to persist in southern Canada and may reseed from agricultural sites.

The McAlpine Tract population was found on a roadside in a rural, agricultural area, presumably introduced through use as a pasture plant. It is not clear how long the population has been established at that site. The Desjardins Canal Park population arose from soil salvaged (in 2014) from a development site in Oakville, Ontario (A. Bell, personal communication) for site restoration purposes. The Desjardins Canal Park population, then, may have persisted here for as long as two years.

Trifolium resupinatum remains a rarely reported introduction in Canada. However, its discovery in two

widely separated southern Ontario sites in different habitats suggests that it may be found elsewhere in agricultural regions of southern Canada.

Voucher specimens

Canada, Ontario: Middlesex County, McAlpine Tract, St. Clair Region Conservation Authority property, weedy roadside, flowers small and pink, rare, mixed with *T. hybridum*, 42.7953°N, 81.8296°W, 25 August 2005, M. J. Oldham, K. McIntyre, J. Labrecque, R. Gould, N. Cavallin, and N. Lavoie, Collection Number 31945 (NHIC, MICH); City of Hamilton, Desjardins Canal Park, Hamilton Conservation Authority property, roughly 50 plants scattered on disturbed ground, with *Lolium perenne*, *Lotus corniculatus*, *Trifolium repens*, *Melilotus officinalis*, *Medicago sativa*, *Bromus hordeaceus*, *Vicia cracca*, 43.26699°N, 79.94208°W, 17 June 2016, C. J. Chapman, Collection number 2016-135 (HAM, DAO, NHIC).

Acknowledgements

We thank Alexander Bell and Lesley McDonnell of Hamilton Conservation Authority for permission to collect and background information on the Desjardins Canal Park site. We also thank Stephen Clayden of the New Brunswick Museum, Sean Blaney of the Atlantic Canada Conservation Data Centre, and Normand Dignard of the Herbarier du Québec for their comments on the presence of *Trifolium resupinatum* in Canada. Tony Reznicek confirmed the identification of the Middlesex County collection. Colin Chapman thanks Angelique Mori and Keith Watkins of Dundas Turtle Watch for sharing in the discovery of the Desjardins Canal Park population. Daniel Brunton, Ian MacDonald, and Paul Catling provided helpful comments on the manuscript.

Literature Cited

- Brouillet, L., F. Coursol, M. Favreau, M. Anions, P. Bélisle, and P. Desmet. 2010+. VASCAN, the database of vascular plants of Canada. Accessed 30 June 2016. <http://data.canadensys.net/vascan>.
- Carr, P. M., W. W. Poland, and L. J. Tisor. 2005. Forage legume regeneration from the soil seed bank in Western North Dakota. *Agronomy Journal* 97: 505–513. <https://doi.org/10.2134/agronj2005.0505>
- Davis, P. H. 1970. *Flora of Turkey and the East Aegean Islands*. Edinburgh University Press, Edinburgh, United Kingdom.
- Fowler, J. 1879. List of New Brunswick plants. Report of the Secretary for Agriculture [1878], Appendix B. Fredericton, New Brunswick, Canada. <https://doi.org/10.5962/bhl.title.63546>
- Gillett, J. M., and T. S. Cochran. 1973. Preliminary reports on the flora of Wisconsin, no. 63. The genus *Trifolium*—the clovers. *Transactions of the Wisconsin Academy of Science* 61: 59–74.
- Haines, A. 2011. *Flora Novae Angliae, A Manual for the Identification of Native and Naturalized Higher Vascular Plants of New England*. Yale University Press, New Haven, Connecticut, USA.

- Hinds, H. R., C. M. Young, and S. R. Clayden.** 2000. Flora of New Brunswick: A Manual for the Identification of the Vascular Plants of New Brunswick. Department of Biology, University of New Brunswick, Fredericton, New Brunswick, Canada.
- Macoun, J.** 1883–1890. Catalogue of Canadian Plants. Parts I–V. Geological Survey of Canada, Ottawa, Ontario, Canada. <https://doi.org/10.5962/bhl.title.54137>
- Magness, J. R., G. M. Markle, and C. C. Compton.** 1971. Food and feed crops of the United States: a descriptive list classified according to potentials for pesticide residues. Bulletin. New Jersey Agricultural Experiment Station, New Brunswick, New Jersey, USA.
- Meikle, R. D.** 1977. Flora of Cyprus. Royal Botanical Gardens, Kew, London, United Kingdom.
- Natural Resources Canada.** 2016. Plant Hardiness Zone by Municipality. Natural Resources Canada, Ottawa, Ontario, Canada. Accessed 3 July 2016. <http://www.planthardiness.gc.ca/?m=22&lang=en>.
- Oldham, M. J.** 2016. Ontario Vascular Plants List. Ontario Natural Heritage Information Centre, Ontario Ministry of Natural Resources and Forestry, Toronto, Ontario, Canada. Accessed 16 June 2016. http://www.sse.gov.on.ca/sites/MNR-PublicDocs/EN/ProvincialServices/Ontario_Vascular_Plants.xlsx.
- Townsend, C. C., and E. Guest.** 1974. Flora of Iraq, Volume 3: Leguminales. Ministry of Agriculture & Agrarian Reform, Baghdad, Iraq.
- USDA (United States Department of Agriculture).** 2012. Plant hardiness zone map. Agricultural Research Service, USDA, Washington, DC, USA. Accessed 3 July 2016. <http://planthardiness.ars.usda.gov>.
- Voss, E. G., and A. A. Reznicek.** 2012. Field Manual of Michigan Flora. University of Michigan Press, Chicago, Illinois, USA. <https://doi.org/10.3998/mpub.345399>
- Zohary, M.** 1972. Flora Palaestina, Part 2: Platanaceae to Umbelliferae. Israel Academy of Sciences and Humanities, Jerusalem, Israel.
- Zohary, M., and D. Heller.** 1984. The Genus *Trifolium*. Israel Academy of Sciences and Humanities, Jerusalem, Israel.

Received 17 October 2016

Accepted 15 September 2017

First Occurrence of a Juvenile Chain Pickerel (*Esox niger*) in Ontario Waters of Lake Ontario

BRIAN P. MORRISON^{1, 2, 4} and DANIEL J. MOORE³

¹Ganaraska Region Conservation Authority, 2216 County Road 28, Port Hope, Ontario L1A 3V8 Canada

²Current address: 2620 Farmerest Avenue, Peterborough, Ontario K9L 1H7 Canada

³Central Lake Ontario Conservation Authority, 100 Whiting Avenue, Oshawa, Ontario L1H 3T3 Canada

⁴Corresponding author: brianmorrison@trentu.ca

Morrison, Brian P., and Daniel J. Moore. 2017. First occurrence of a juvenile Chain Pickerel (*Esox niger*) in Ontario waters of Lake Ontario. *Canadian Field-Naturalist* 131(4): 331–334. <https://doi.org/10.22621/cfn.v131i4.1946>

This paper documents the first juvenile Chain Pickerel (*Esox niger*) captured in Ontario waters of Lake Ontario. It was found during August 2016 monitoring activities at Port of Newcastle. Its occurrence represents a significant westward range expansion from recently documented adults in the eastern basin of Lake Ontario Bay of Quinte St. Lawrence River, likely colonizing from United States waters of Lake Ontario.

Key Words: *Esox niger*; Chain Pickerel; range expansion; Ontario; Lake Ontario

Introduction

Chain Pickerel (*Esox niger*) is a small- to medium-sized (adult total length 381–762 mm), largely piscivorous member of the pike family (Esocidae), which usually inhabits lakes and large rivers with associated submerged aquatic vegetation and water depths of less than 3 m (Scott and Crossman 1998). Its native range is principally the Atlantic coastal plains, including parts of the St. Lawrence River, the New York (south) shore of Lake Ontario, and portions of Quebec. It is considered naturalized in New Brunswick, Nova Scotia, and other parts of Quebec (Greeley 1939; Coffie 1998; Page and Burr 2011; Carlson *et al.* 2016), with introductions expanding its range west of this (Coffie 1998).

Chain Pickerel has been widely introduced as a sport fish and has subsequently expanded its range in many parts of the United States and eastern Canada (Coffie 1998). Adult Chain Pickerel, native to the United States waters of Lake Ontario (Holm *et al.* 2009), were first confirmed in the eastern basin of Lake Ontario between 2008 and 2010 (Hoyle and Lake 2011). Adult Chain Pickerel have continued to be present in the upper St. Lawrence/eastern Lake Ontario basin (J. Hoyle, personal communication), with evidence of natural reproduction on the New York side of the eastern basin of Lake Ontario (Carlson *et al.* 2016). Hoyle and Lake (2011) speculated that range expansion west of the Bay of Quinte may be more difficult because the shoreline is largely devoid of warm, vegetated waters.

This paper documents the first occurrence of a juvenile Chain Pickerel in Canadian waters of Lake Ontario and a significant range expansion to the north shore of Lake Ontario.

Methods

Annual monitoring occurs across a series of Lake Ontario coastal wetland habitats as part of the Durham

Region Coastal Wetland Monitoring Program (DRC-WMP) and Bay of Quinte Remedial Action Plan. Sixteen wetlands are sampled annually in the Durham region and 15 wetlands are sampled on a 3-year rotation in the Bay of Quinte (Figure 1). The DRCWMP protocol is used at both locations; it notes fisheries, vegetation, and chemical characteristics of each wetland at the time of sampling (Environment Canada and Central Lake Ontario Conservation Authority 2007; Moore 2016).

Fishes are sampled via boat electrofishing along a linear transect, with six sampling points located 8 m apart, resulting in approximately 4-m-diameter sampling points along the 44-m transect. Each point along the transect is sampled for 20 electrofishing seconds, with one crew member netting all fishes for later processing. Genetic species identification was conducted by barcoding at the CO1 mitochondrial gene and cross-referencing sequences with the GENBANK database.

Results

On 22 August 2016, a 153-mm total length, 19-g juvenile Chain Pickerel (Figure 2) was captured by boat electrofishing at Port of Newcastle wetland (43°53'50.0172"N, 78°34'37.7322"W) during annual monitoring activities. The fish was considered a juvenile based on its size. It was preserved in 95% ethanol and sent to the Royal Ontario Museum for verification (ROM 101354).

The specimen had 15 branchiostegal rays, fully scaled gill covers, a prominent suborbital bar that does not slope backward, four pores on the ventral side of each mandible, and snout length greater than the distance from back of eye to top of gill slit (Table 1). In addition, DNA was extracted from the Chain Pickerel and it was positively identified using the GENBANK database, i.e., the CO1 mitochondrial gene (barcode) matched other Chain Pickerel sequences (799 base pairs

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalists' Club.

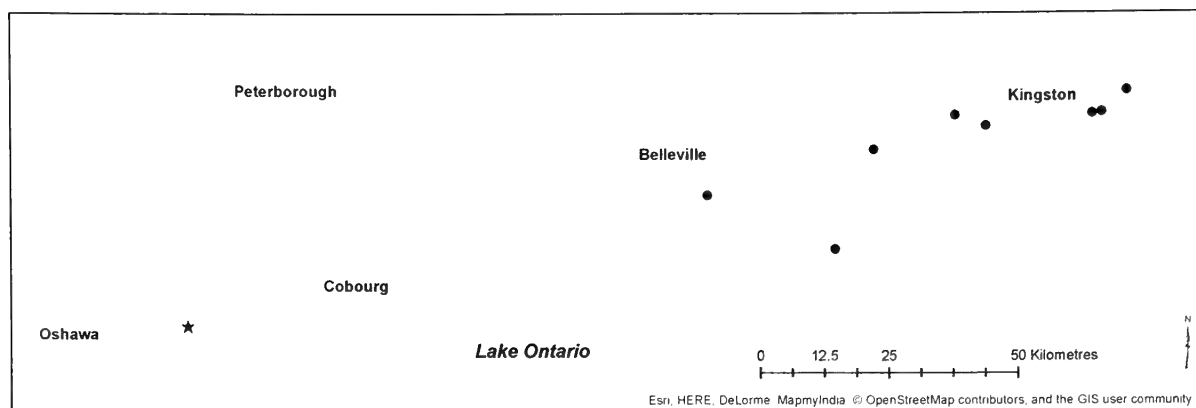


FIGURE 1. Location of juvenile Chain Pickerel (*Esox niger*) captured at Port of Newcastle (star) and recent adult Chain Pickerel captures in the Bay of Quinte and eastern basin of Lake Ontario (black dots).

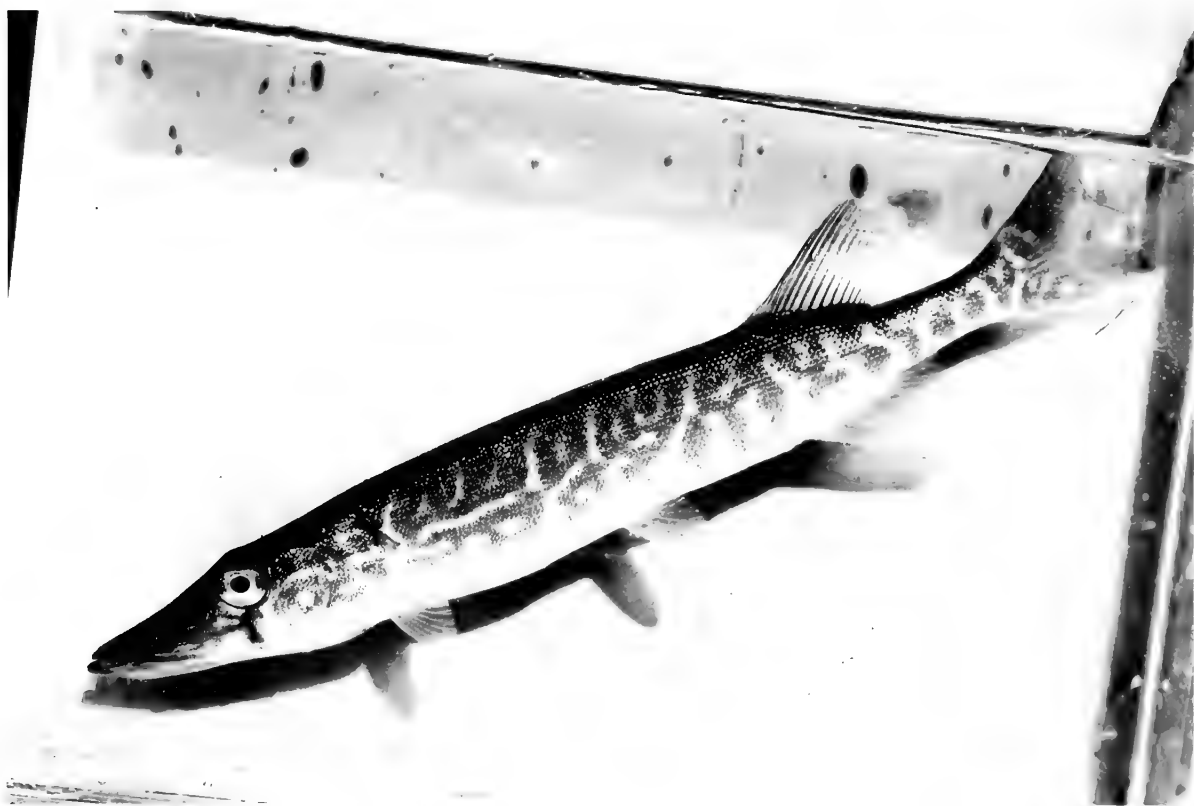


FIGURE 2. First juvenile Chain Pickerel (*Esox niger*) caught in Ontario (total length 153 mm). Photo: B. Morrison.

of 802 matched; E. Holm and H. Haddrath, personal communications). Subsequent supplemental monitoring on 1 September 2016, using both boat electrofishing and seining, failed to detect any additional specimens.

Other fish species captured on 22 August 2016 in the Port of Newcastle wetland included Common Carp (*Cyprinus carpio*), Johnny Darter (*Etheostoma nigrum*), Largemouth Bass (*Micropterus salmoides*), Pumpkinseed (*Lepomis gibbosus*), Rock Bass (*Ambloplites rupestris*), and Round Goby (*Neogobius melanostomus*).

Turbidity and conductivity in this coastal wetland were 5–15 nephelometric turbidity units (NTU) and 300–500 $\mu\text{S}/\text{cm}$, respectively, based on sampling in 2016 and earlier. Total aquatic plant cover at this location was around 60% and included Curly-leaved Pondweed (*Potamogeton crispus* L.), Eurasian Water-milfoil (*Myriophyllum spicatum* L.), Small Pondweed (*Potamogeton pusillus* L.), and Leafy Pondweed (*Potamogeton foliosus* Rafinesque). The substrate was quite coarse, consisting of a mix of contents from old gabion baskets and silt/sand. Aquatic vegetation throughout the marsh was inter-

TABLE 1. Identification features of Ontario esocids.

Species	No. branchiostegal rays	Gill cover	Suborbital bar	No. lower jaw pores
Chain Pickerel (<i>Esox niger</i>)	14-17	Fully sealed		8 (4 on each side)
Grass Pickerel (<i>Esox americanus vermiculatus</i>)	11-13	Fully sealed	Prominent	8 (4 on each side)
Northern Pike (<i>Esox lucius</i>)	14-15	Partly sealed		10 (5 on each side)
Muskellunge (<i>Esox masquinongy</i>)	16-19	Partly sealed		12-18 (6-9 on each side)

spersed with pockets of well-vegetated areas, but most of the area had little cover. Port of Newcastle is considered a drowned river mouth; a portion has been dredged for a marina.

Discussion

Chain Pickerel is believed to be native in New York waters of Lake Ontario (Carlson *et al.* 2016, and references within), but it has recently colonized Ontario waters in the eastern basin and upper St. Lawrence River, with increasing abundance in the former (Hoyle and Lake 2011). The capture of this Chain Pickerel is significant, as it is both the first juvenile captured, and its location was more than 100 km west of the closest record in Ontario waters.

Chain Pickerel have remained elusive in the Lake Ontario basin despite significant sampling in warm, highly vegetated habitats. Since 2002, 185 wetland sampling events have been completed in the Durham region and 50 in the Bay of Quinte under the DRCWMP. In addition, other agencies, largely the Ontario Ministry of Natural Resources and Forestry, carry out sampling in the Bay of Quinte using numerous gear types, and commercial fisheries expend a large amount of effort in the bay (Ontario Ministry of Natural Resources and Forestry 2016). Although significant wetland sampling occurs in the Durham region, limited sampling is done in adjacent Lake Ontario nearshore waters. The absence of adult records in the Durham region could be attributed to low abundance, a low sampling effort in areas with water depth greater than 2 m, and the timing of DRCWMP sampling, i.e., after adult fish have spawned and left wetland habitats (Environmental Canada and Central Lake Ontario Conservation Authority 2007; Sauvanet *et al.* 2013). Samarasin *et al.* (2017) have noted that sampling effort should be greater (either single or replicate sampling) in areas with more species and in larger wetlands to improve chances of detection. In addition to varying effort, challenges differentiating juvenile Chain Pickerel from other Esocidae could be complicating the recognition of range expansion.

Range expansion is difficult to monitor because of the rarity of a species at its leading edge and the potential for misidentification and hybridization with similar species. Although, not certain, it is unlikely that this specimen was introduced (e.g., via bait bucket or aquarium release); thus, this capture is likely evidence that the range of the Chain Pickerel is expanding westward

in Ontario and that natural reproduction may have occurred in the Port of Newcastle wetland. It is unclear what role a significant drought in 2016 may have played in forcing fishes out of small coastal wetlands and concentrating them in larger wetland complexes with easy access from Lake Ontario, such as Port of Newcastle. Continued monitoring, with increased emphasis on areas that have been poorly sampled, should help determine abundance and confirm natural reproduction of Chain Pickerel in the Ontario waters of Lake Ontario.

Although the captured specimen appears to be a pure Chain Pickerel, it is possible that hybrids between Chain Pickerel and Northern Pike (*Esox lucius*) maybe present. Such a hybrid would be difficult to identify, and we recommend that any *Esox* that is not clearly a Northern Pike or Grass Pickerel be preserved and a tissue sample saved for genetic analysis. Specimens and tissues can be submitted for identification to the Royal Ontario Museum.

Limitations on the Chain Pickerel's range expansion are thought to be related to water temperatures and the amount of suitable habitat. Mandrak (1989) predicted that climate warming might lead to further expansion and establishment of Chain Pickerel in Ontario waters of Lake Ontario or connected waterbodies. Hoyle and Lake (2011) indicated that the lack of warm, heavily vegetated habitats in portions of Lake Ontario could create physical barriers to Chain Pickerel dispersal. Although the north shore of Lake Ontario has limited habitat for Chain Pickerel, the fish appears to have bridged this barrier. It is unknown how such habitat features affect dispersal of Chain Pickerel at various life stages or what mechanisms prompt movement or colonization. It is also not known what impact this species might have on existing fish communities, its potential for hybridization with other Esocidae (e.g., *E. lucius*), or its effect on recreational and commercial fisheries. Chain Pickerel have been implicated in simplifying fish communities, reducing overall fish abundance, and truncating the size spectrum of fishes in waterbodies where it has been introduced (Mitchell *et al.* 2010), but these effects may be muted because piscivorous species are already present in the existing fish community. Continued monitoring is encouraged to track the continued presence and establishment of Chain Pickerel in Ontario waters.

Acknowledgements

We thank Erling Holm (Royal Ontario Museum) for confirming identification, participating in subsequent sampling, encouraging us to document this occurrence, and reviewing the manuscript. We also thank Oliver Hadrath (Royal Ontario Museum) for genetic analysis; Jim Hoyle and Colin Lake (Lake Ontario Management Unit, Ontario Ministry of Natural Resources and Forestry) for their comments and perspectives on Chain Pickerel status in Lake Ontario; Mike Parna, Anna Miles, and Robin Brand for their assistance in the field; and Dr. Nicholas Mandrak and an anonymous reviewer whose comments and suggestions greatly improved this manuscript.

Literature Cited

- Carlson, D. M., R. A. Daniels, and J. J. Wright.** 2016. Atlas of Inland Fishes of New York. Volume 7. New York State Museum, Albany, New York, USA.
- Coffie, P. A.** 1998. Status of the Chain Pickerel, *Esox niger*, in Canada. *Canadian Field-Naturalist* 112: 133–140. Accessed 27 March 2018. <https://www.biodiversitylibrary.org/item/106776#page/141/mode/1up>.
- Environment Canada and Central Lake Ontario Conservation Authority.** 2007. Durham Region Coastal Wetland Monitoring Project: Methodology Handbook. Central Lake Ontario Conservation Authority, Oshawa, Ontario, Canada.
- Greeley, J. R.** 1939. Fishes of the watershed with annotated list. In *A Biological Survey of the Lake Ontario Watershed (Including all Waters from Little Sandy Creek Westward Except the Genesee and Oswego River Systems): Supplement to the Twenty-ninth Annual Report, 1939, Volume 16*. New York (State) Conservation Department, Albany, New York, USA.
- Holm, E., N. Mandrak, and M. Burridge.** 2009. The ROM Field Guide to Freshwater Fishes of Ontario. Royal Ontario Museum, Toronto, Ontario, Canada.
- Hoyle, J. A., and C. Lake.** 2011. First occurrence of Chain Pickerel (*Esox niger*) in Ontario: possible range expansion from New York waters of eastern Lake Ontario. *Canadian Field-Naturalist* 125: 16–21. <https://doi.org/10.22621/cfn.v125i1.1116>
- Mandrak, N. E.** 1989. Potential invasion of the Great Lakes by fish species associated with climatic warming. *Journal of Great Lakes Research* 15: 306–316. [https://doi.org/10.1016/S0380-1330\(89\)71484-2](https://doi.org/10.1016/S0380-1330(89)71484-2)
- Mitchell, S. C., J. E. LeBlanc, and A. J. Heggelin.** 2010. Impact of introduced Chain Pickerel (*Esox niger*) on lake fish communities in Nova Scotia, Canada. Nova Scotia Department of Fisheries and Aquaculture, Halifax, Nova Scotia, Canada.
- Moore, D. M.** 2016. The use of historical data to describe changes in fish communities over time. M.E.Sc. thesis, University of Toronto, Scarborough, Ontario, Canada.
- Ontario Ministry of Natural Resources and Forestry.** 2016. Lake Ontario fish communities and fisheries: 2015 annual report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources and Forestry, Picton, Ontario, Canada.
- Page, L. M., and B. M. Burr.** 2011. A Field Guide to Freshwater Fishes of North America North of Mexico. Houghton Mifflin Harcourt, Boston, Massachusetts, USA.
- Samarasin, P., S. M. Reid, and N. E. Mandrak.** 2017. Optimal sampling effort required to characterize wetland fish communities. *Canadian Journal of Fisheries and Aquatic Sciences* 74: 1251–1259. <https://doi.org/10.1139/cjfas-2016-0424>
- Sauvanet, J., G. Bourdier, J. Colombet, A. Viallefont, C. Lemarchand, and C. Desvillettes.** 2013. Estimating *Esox lucius* (Esocidae, Esociformes) density and population structure in a large European alluvial river: the Allier (France). *Journal of Ichthyology* 53: 617–627. <https://doi.org/10.1134/S003294521305010X>
- Scott, W. B., and E. J. Crossman.** 1998. Freshwater Fishes of Canada. Galt House Publications, Oakville, Ontario, Canada.

Received 13 April 2017

Accepted 29 December 2017

Note

A Bilaterally Partitioned Colour Variant of an Appalachian Brook Crayfish (*Cambarus bartonii bartonii*) from Eastern Pennsylvania

SEAN M. HARTZELL

Department of Biological and Allied Health Sciences, Bloomsburg University of Pennsylvania, 400 East 2nd Street, Bloomsburg, Pennsylvania 17815 USA; email: smh14844@huskies.bloomu.edu

Hartzell, Sean M. 2017. A bilaterally partitioned colour variant of an Appalachian Brook Crayfish (*Cambarus bartonii bartonii*) from eastern Pennsylvania. *Canadian Field-Naturalist* 131(4): 335–337. <https://doi.org/10.22621/cfn.v131i4.1954>

This observation of a bilaterally partitioned colour phenotype of an Appalachian Brook Crayfish (*Cambarus bartonii bartonii*) from Fishing Creek, Columbia County, Pennsylvania, USA, appears to be the first report of such an aberrant phenotype for this species. The pattern is similar to that reported previously in Papershell Crayfish (*Orconectes immunis*) and American Lobster (*Homarus americanus*). Although the cause of the colour pattern in the specimen of *C. b. bartonii* could not be determined, hypotheses related to previous cases in aquatic crustaceans include bilateral partition of primary and secondary sexual characteristics (bicoloured gynandromorphy) and mutation during embryogenesis.

Key Words: Appalachian Brook Crayfish; *Cambarus bartonii bartonii*; colour variation; bilateral partition; bicoloured gynandromorphy; Pennsylvania

Appalachian Brook Crayfish (*Cambarus bartonii bartonii*) is a small- to medium-sized crayfish occupying primarily lotic habitats from Quebec, Ontario, and New Brunswick in Canada south to Georgia, South Carolina, and Alabama in the United States (Hobbs 1989). Colouration in *C. b. bartonii* typically ranges from a single shade of olive green through amber, brown, and chestnut (Ortmann 1906; Martin 1997; Loughman 2010).

On 22 September 2016, I collected a single atypically coloured *C. b. bartonii* from among 108 crayfish captured while conducting a crayfish survey of Fishing Creek, a tributary of the North Branch Susquehanna River, near the municipality of Stillwater, Columbia County, Pennsylvania, USA (41°07'46.6"N, 76°21'37.1"W; Hartzell and Rier 2017). Here I provide a description and context for the significance of this observation.

The atypical specimen was captured by hand from under a piece of cobble at the margin of Fishing Creek, identified to species, photographed, measured, and released at the site of capture. The specimen, carapace length 2.6 cm and undetermined sex, exhibited a largely bilaterally partitioned colour pattern from the posterior portion of the cephalothorax through to the telson, with the left half of the body a dark, olive green and the right half a light amber in colour. The anterior portion of the cephalothorax was dark, olive green (Figure 1). The specimen appeared to be in excellent condition and displayed normal, unimpeded behaviour (e.g., walking, a righting response, aggressive defense with chelae during handling).

The colour pattern reported here suggests a condition referred to as “bilateral gynandromorphy”, which has been documented in various crustaceans, including lobsters, crabs, prawns, and other decapods (e.g., Chace



FIGURE 1. Appalachian Brook Crayfish (*Cambarus bartonii bartonii*) from northeastern Pennsylvania displaying a bilaterally partitioned colour phenotype. Photo: Sean M. Hartzell.

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalists' Club.

and Moore 1959; Farmer 1972; Syslo and Hughes 1981; Taylor 1986; Micheli 1991), as well as in other invertebrates, such as ants (Taber and Francke 1986) and even vertebrates, such as birds (Peer and Motz 2014). These individuals may display a bilateral partition of colouration, termed “bicoloured bilateral gynandromorphy”. The condition is most obvious in species with sexually dimorphic colour patterns (e.g., Peer and Motz 2014). In Pennsylvania, *C. b. bartonii* appears to exhibit an ontogenetic colour shift from greener hues in younger individuals to darker brown in older specimens (Ortmann 1906), but does not appear to exhibit obvious sexual dimorphism in colouration. Although Ortmann (1906) reported two specimens of *C. b. bartonii* from Pennsylvania that displayed a mixture of male and female sexual characteristics, his lack of comment on colouration suggests that they were of normal phenotype.

Bicoloured gynandromorphy may also occur among species lacking distinct sexual dimorphism in colouration, but where some degree of colour variation is prevalent. Chace and Moore (1959) described an American Lobster (*Homarus americanus*) with a bilaterally distinct colour partition made evident by the absence of blue pigment on the left side of the body and the absence of red, yellow, and black pigments on the right side. This occurred in conjunction with bilateral partition of primary and secondary sexual characteristics. An observation of colour bilateralism similar to that reported here involves Papershell Crayfish (*Orconectes immunis*; Dowell and Winier 1969). Dowell and Winier (1969) rejected gynandromorphy as a causative mechanism because this crayfish displayed only female external sexual characteristics, and they speculated that its bicolouration was the result of a mutation during embryogenesis. However, because neither the specimen reported by Dowell and Winier (1969) nor the *C. b. bartonii* reported here was examined internally to determine sex or intersexual status, any suggestion of the lack of a link between colour pattern and gynandromorphy in these specimens remains speculative.

Colouration in crayfish can vary and change because of environmental factors, including the hue of the background substrate (Bowman 1942; Thacker *et al.* 1993). However, it is unlikely that the colour pattern I observed may be attributed to background colour matching because of the striking bilateral partitioning. In addition, the specimen remained in a white cooler for approximately an hour with other crayfish collected at the site before being photographed, measured, and released, with no obvious shift in colour pattern.

Given that all other *C. b. bartonii* captured in Fishing Creek during the 2016 survey displayed typical colour phenotypes (i.e., a single colour varying from olive green to light amber) and that the observation reported here appears to be unique for the species, the bilaterally partitioned phenotype would appear to be

exceedingly rare in *C. b. bartonii*. Collection and dissection, or genomic analysis, of additional specimens of crayfish showing colour bilateralism may provide insight into the cause of this phenomenon.

Acknowledgements

I thank Steven T. Rier for support and guidance through the course of the project during which this observation was made. I also thank Dr. Donald McAlpine, Dr. Dwayne Lepitzki, and two anonymous reviewers for comments and suggestions that greatly improved this manuscript. Crayfish research was permitted by the Pennsylvania Fish and Boat Commission (permit 2016-01-0430, type 1).

Literature Cited

- Bowman, T. E.** 1942. Morphological color change in crayfish. *American Naturalist* 76: 332–336. <https://doi.org/10.1086/281051>
- Chase, Jr., F. A., and G. M. Moore.** 1959. A bicolored gynandromorphy of the lobster, *Homarus americanus*. *Biological Bulletin* 116: 266–231. <https://doi.org/10.2307/1539207>
- Dowell, V. E., and L. P. Winier.** 1969. A bilateral color anomaly in the crayfish *Orconectes immunis* (Hagen). *Proceedings of the Iowa Academy of Science* 76: 487–492.
- Farmer, A. S.** 1972. A bilateral gynandromorph of *Nephrops norvegicus* (Decapoda: Nephropidae). *Marine Biology* 15: 344–349. <https://doi.org/10.1007/BF00401394>
- Hartzell, S. M., and S. T. Rier.** 2017. A crayfish survey of the Fishing Creek watershed in northeastern Pennsylvania reveals widespread prevalence of a non-indigenous species and the absence of an indigenous congener. *Journal of the Pennsylvania Academy of Science* 91: 1–10. <https://doi.org/10.5325/jpennacadsci.91.1.0001>
- Hobbs, Jr., H. H.** 1989. *An Illustrated Checklist of the American Crayfishes* (Decapoda: Astacidae, Cambaridae, Parastacidae). Smithsonian Institution Press, Washington, DC, USA. <https://doi.org/10.5479/si.00810282.480>
- Loughman, Z. J.** 2010. Crayfishes of western Maryland: conservation and natural history. *Southeastern Naturalist* 9 (special issue 3): 33–62. <https://doi.org/10.1656/058.009.s303>
- Martin, S. M.** 1997. Crayfishes (Crustacea: Decapoda) of Maine. *Northeastern Naturalist* 4: 165–188. <https://doi.org/10.2307/3858712>
- Micheli, F.** 1991. Bilateral gynandromorph of the fresh-water crab *Potamon fluviatile* Herbst (Decapoda: Brachyura). *Journal of Crustacean Biology* 11: 561–568. <https://doi.org/10.2307/1548526>
- Ortmann, A. E.** 1906. The crawfishes of the state of Pennsylvania. *Memoirs of the Carnegie Museum* 2: 343–523. <https://doi.org/10.5962/bhl.title.10407>
- Peer, B. D., and R. W. Motz.** 2014. Observations of a bilateral gynandromorph northern cardinal (*Cardinalis cardinalis*). *Wilson Journal of Ornithology* 126: 778–781. <https://doi.org/10.1676/14-025.1>
- Syslo, M., and J. T. Hughes.** 1981. Reproductive behavior of a bicolored gynandromorphic American lobster. *Progressive Fish-Culturalist* 43: 214–216. [https://doi.org/10.1577/1548-8659\(1981\)43\[214:RBOABG\]2.0.CO;2](https://doi.org/10.1577/1548-8659(1981)43[214:RBOABG]2.0.CO;2)

Taber, S. W., and O. E. Francke. 1986. A bilateral gynandromorph of the western harvester ant, *Pogonomymex occidentalis* (Hymenoptera: Formicidae). *Southwestern Naturalist* 31: 274–276. <https://doi.org/10.2307/3670583>

Taylor, D. M. 1986. A bilateral gynandromorph of the snow crab, *Chionoecetes opilio*, from Newfoundland, Canada. *Crustaceana* 51: 309–312. <https://doi.org/10.1163/156854086X005024086X00502>

Thacker, R. W., B. A. Hazlett, L. A. Esman, C. P. Stafford, and T. Keller. 1993. Color morphs of the crayfish *Oreo-nectes viridis*. *American Midland Naturalist* 129: 182–199. <https://doi.org/10.2307/2426447>

Received 26 May 2017

Accepted 2 January 2018

Increased Bufflehead (*Bucephala albeola*) Breeding Activity in Minnesota

SUSAN N. ELLIS-FELEGÉ^{1,4}, CASSANDRA G. SKAGGS^{1,3}, and GREGORY A. KNUTSEN²

¹Biology Department, University of North Dakota, 10 Cornell Street, Stop 9019, Grand Forks, North Dakota 58202-9019 USA

²U.S. Fish and Wildlife Service, Glacial Ridge and Rydell National Wildlife Refuges, 17788 349th Street SE, Erskine, Minnesota 56535 USA

³Louisiana State University, School of Renewable Natural Resources, LSU Agricultural Center, Baton Rouge, Louisiana 70803 USA

⁴Corresponding author: susan.felege@email.und.edu

Ellis-Felege, Susan N., Cassandra G. Skaggs, and Gregory A. Knutsen. 2017. Increased Bufflehead (*Bucephala albeola*) breeding activity in Minnesota. *Canadian Field-Naturalist* 131(4): 338–343. <https://doi.org/10.22621/cfn.v131i4.1963>

Buffleheads (*Bucephala albeola*) predominantly nest in the boreal forests and aspen parklands of Canada and Alaska. Historically, Buffleheads were common migrants but not summer residents in Minnesota. However, recent observations in Minnesota and surrounding states suggest increased breeding activity in the region. In 1978, the first Bufflehead brood in Minnesota was recorded at East Park Wildlife Management Area. Annually, Agassiz National Wildlife Refuge (NWR) has conducted pair and brood surveys, with species-specific records available from 1990 to 2014. We report an increase in numbers of Bufflehead breeding pairs and broods at Agassiz NWR and new pair observations in surrounding areas.

Key Words: Breeding range; *Bucephala albeola*; Bufflehead; cavity nesting; expansion; Great Plains; upper midwest

Introduction

Buffleheads (*Bucephala albeola*) are a secondary cavity-nesting species that frequently use the cavities of Northern Flickers (*Colaptes auratus*) and, to a lesser extent, Pileated Woodpeckers (*Dryocopus pileatus*). Nest cavities used by Buffleheads are most common in live or dead poplar or aspen trees (*Populus* spp.). They also will use nest boxes (Gauthier 1988). Most Bufflehead nesting activity occurs in Canada and Alaska, with a smaller portion of the breeding population extending into parts of Washington, California, Oregon, Idaho, Montana, and Wyoming (Erskine 1972; Gauthier 2014). Although this small, cavity-nesting duck is a common fall and spring migrant throughout much of Minnesota, it is considered a rare summer resident (Janssen 1987; Gauthier 2014). Erskine (1972) suggested Buffleheads may have been present in early summer in northwestern Minnesota, but that most of these individuals were subadults or non-breeding adults that would remain in the region into the breeding season. Scattered historical breeding records do exist for North Dakota (1873), Iowa (1880s), Wisconsin (1903), South Dakota (1949), Idaho (1953), and more recently Nevada (Floyd *et al.* 2007). It was not until 1978, however, that the first Bufflehead brood in Minnesota was documented at East Park Wildlife Management Area (WMA) in the northwestern part of the state (Davis 1978). An increasing number of reports of breeding activity occurred over the next 10 years across northwestern Minnesota (Heidel 1983; Mattsson 1986). Since 1985, Bufflehead broods have been observed at Agassiz National Wildlife Refuge (NWR), located in northwestern Minnesota, almost every year.

Recent observations have documented Bufflehead breeding activity in the southern half of Minnesota, including a 2012 brood in Cottonwood County in southern Minnesota (Pfannmuller *et al.* 2017). Additionally, broods have recently been confirmed in southeastern Wisconsin (Bahl and Bartholmai 2011), south-central and eastern North Dakota (Knutsen and King 2004; M. R. Fisher, personal communication, 2012), and north-eastern South Dakota (Whitt 1999). Scattered observations reported to eBird document Buffleheads during June and July in areas as far south as Texas and Louisiana (eBird 2012). These observations across the upper midwest (Wisconsin, Minnesota, North Dakota, South Dakota) and Great Plains suggest that Buffleheads may be increasing their breeding activities. Our objective was to evaluate changes in Bufflehead reproductive activity in northwestern Minnesota and summarize recent accounts of breeding activity across the upper midwest region.

Study Area

Long-term monitoring of Bufflehead reproduction was conducted at Agassiz NWR (centroid 48.315836°N, 95.947023°W), Marshall County, Minnesota (Figure 1). Agassiz NWR was established in 1937 as a “refuge and breeding ground for migratory birds and other wildlife”. The refuge is 24889 ha in total, including 15 136 ha of wetland habitat, 4715 ha of shrubland, 4007 ha of woodland (primarily aspen), and 737 ha of grassland. Wetland area includes 26 impoundments that range in size from 12 to > 4000 ha and are managed as sedge meadow and emergent marsh habitats (USFWS 2005). Recent man-

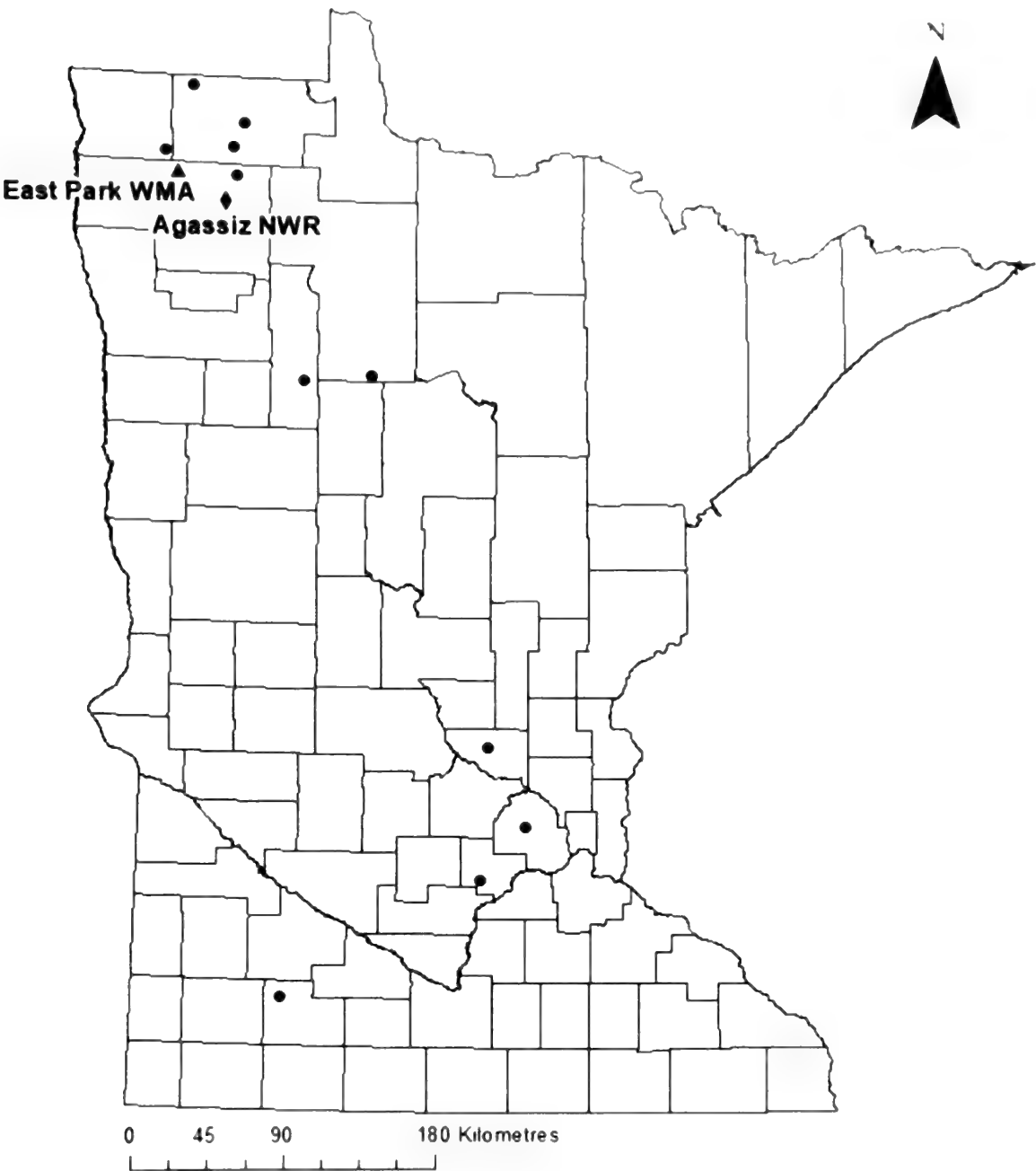


FIGURE 1. Reported or suspected Bufflehead (*Bucephala albeola*) breeding activity in Minnesota, 1978–2014. East Park Wildlife Management Area (WMA) had the first Bufflehead observation in 1978 (triangle), and Agassiz National Wildlife Refuge (NWR) had the most observations overall (diamond). Observations outside study area (solid circles) were obtained from Pardieck *et al.* (2016).

agement efforts have focussed on controlling overabundant cattails across the refuge.

Historically, the area that is now Agassiz NWR was a boggy wilderness, checkered with wetlands and ponds. After European settlement in the 1890s, wetlands were drained for agriculture which resulted in more than 1900 km of county and legal drainage ditches. Agassiz NWR lies within the aspen parkland transitional zone (USFWS 2005). Climatic conditions at the refuge are typical of the region, where variation in temperatures is

wide and extreme, including cold winters with moderate snowfall and approximately 56 cm of annual precipitation (USFWS 1978).

In addition to Agassiz NWR, we conducted roadside surveys at six wildlife management areas, two flood storage impoundments, and one state park in northwestern Minnesota to determine the extent of breeding occurrences in the region (Table 1). Of these, five sites had no prior reports of Bufflehead activity during the breeding season whereas five others did (Table 1).

TABLE 1. Maximum number of Bufflehead (*Bucephala albeola*) pairs observed during spring roadside surveys at five sites with previous records of pairs (noted with an *) and five sites with no previous records located in northwestern Minnesota, 2012–2013.

Site	Bufflehead Breeding Pair Summary for 2012 and 2013					Max. pairs detected outside of survey constraints (2012/2013) [†]
	Max. pairs 2012	Max. pairs 2013	Change in pairs from 2012	Newly detected site 2012	Newly detected site 2013	
Agassiz NWR East*	10	8	−2	—	—	2/4
Agassiz NWR South*	3	2	−1	—	—	2/0
Agassiz NWR West*	5	4	−1	—	—	2/2
Agassiz Valley Project	0	0	0	No	No	0/1
East Park WMA*	2	2	0	—	—	3/2
Hayes Lake State Park	0	0	0	No	No	0/0
Moose River Impoundment	0	2	2	No	Yes	0/0
Nereson WMA*	0	3	3	—	—	1/2
Red Lake WMA	0	1	1	No	Yes	0/0
Roseau River WMA*	4	3	−1	—	—	3/1
Thief Lake WMA*	1	1	0	—	—	0/1
Twin Lakes WMA	1	0	−1	Yes	No	0/0

*Known breeding locations before 2012.
[†]Pairs observed but not included in our other counts (e.g., pairs observed outside of our defined survey area or between points). The first number is the maximum number of pairs observed in 2012 and the second number is the maximum number of pairs observed in 2013.

Methods

Breeding duck pair and brood surveys are conducted annually at Agassiz NWR (USFWS 2008). A double sampling method of ground and aerial surveys was used to estimate pairs across one third of the refuge. Ground surveys were conducted using roadside pair counts on a single morning each spring between 16 and 24 May. Observers drove 8–16 km/h on transects totalling 80.5 km within the refuge. Pairs were recorded by species out to 200 m from each transect. Indicated pairs included one male and one female, a lone male, or males in groups of two to five (Hammond 1969). During the completion of ground surveys, 17 aerial transect surveys were flown in a fixed-wing aircraft at an altitude of 45–46 m over the refuge. Two observers, not including the pilot, recorded all indicated duck pairs and classified them as either “diving ducks” or “dabbling ducks” within 200 m on each side of the aircraft. Approximately 38.5 km were concurrently surveyed by both air and ground to provide a ground/air correction factor.

Only ground surveys were used to calculate duck brood estimates. Two separate brood surveys were conducted by driving the same transects as for pair surveys. Surveys were conducted between 5–12 July and 15–23 August, with a minimum of 42 days between surveys to minimize duplicate brood counts. All broods within 200 m of each side of the transect were recorded, identified to species, and aged according to Gollop and Marshall (1954). During the second (August) survey, only ducklings age class IIc (Gollop and Marshall 1954) and younger were counted by trained observers to avoid double counting broods that were recorded during the first survey.

Pair and brood surveys were conducted only on days without steady precipitation and winds not exceeding 24 km/h for pairs and 8 km/h for broods (Giudice 2001). Each survey was initiated 30 min after sunrise and took approximately 3.5–4 h to complete. Due to staff limitations, brood surveys were not conducted in 2013 or 2014.

In 2012 and 2013, we expanded surveys across north-west Minnesota to include other sites where Bufflehead breeding activity may potentially occur. Of the ten sites selected, five had documented broods in past years, whereas five had no documented Bufflehead breeding activity, but possessed potential habitat (Figure 1). Given that aerial surveys were not available across these sites, we conducted repeat count surveys to allow examination of detection while estimating occurrence of potential breeding pairs. Similar to the ground surveys for pairs conducted at Agassiz NWR, roadside surveys were conducted 18–30 May. Observers stopped at points (250 m apart) along routes to count pairs within 200 m of the survey point, because not all wetlands allowed for equal road-based visibility of wetlands.

For the initial Agassiz NWR surveys conducted from 1990 until 2014, we estimated breeding Bufflehead pairs based upon aerial and ground surveys. The total number of pairs for dabbling ducks and diving ducks were calculated from both aerial and ground surveys. The ratio of ground to air (total number of pairs counted from ground/total number of pairs counted from aerial surveys) provides a correction factor between survey methods. Because aerial surveys effectively sampled one third of the refuge, the total number of diver and dabbling pairs tallied during the aerial survey was multiplied by three and the ground/air correction factor to

estimate total number of divers on the refuge. Finally, the number of Bufflehead pairs was obtained by estimating the proportion of divers that were classified as Buffleheads on the ground survey.

We only report summary statistics from broods detected along survey routes for each year, given we had limited information on other aspects of the reproductive process (e.g., nest success, brood survival) that influence productivity. Prior to 2001, surveys were conducted from the bed of the pickup truck with higher elevation. Beginning in 2001, federal safety policy required that all observers conduct surveys from inside the truck's cab instead. Thus, broods observed after 2001 are corrected for detections estimated from concurrent bed and cab surveys that found a 0.65 detection rate from the cab (Agassiz NWR, unpublished data, 1999–2001).

For the 2012–2013 data, we used the maximum pairs or broods detected across three repeated surveys. This allowed us to account for detection issues of missing pairs or broods during some surveys. Due to a limited sample size of wetlands that we could monitor, we did not conduct a formal occupancy analysis to estimate detection (MacKenzie *et al.* 2006).

Results

Bufflehead breeding pair numbers have increased across Agassiz NWR since 1990, with an estimated average of 329 breeding pairs across the refuge over the

most recent 10 years (2004–2014) of data (Figure 2). Over that 10-year period, there was an 84% increase in number of pairs using the refuge. Similarly, the number of brood sightings has an increasing trend since 1990, with an average of 11 (range 0–26) Bufflehead broods detected along survey routes from 2002 through 2012 at Agassiz NWR.

The 2012 and 2013 pair surveys revealed three locations with new occurrences of potential breeding pairs (Table 1). These include new observations at Moose River Impoundment, Red Lake WMA, and Twin Lakes WMA. However, we did not detect broods at any of the sites other than Agassiz NWR during brood surveys in 2012.

Discussion

Based on aerial-ground surveys conducted by U.S. Fish and Wildlife Service since 1990, Bufflehead breeding activity in northwestern Minnesota has rapidly increased since the first brood observation at Agassiz NWR in 1985. Additional observations in North Dakota and the southwest corner of Minnesota (i.e., Cottonwood County) demonstrate other areas with possible breeding populations. Given some historical observations, there may be increased Bufflehead breeding activity occurring in areas south of what was thought to be the traditional breeding range of the species. A southward range expansion in California also has been docu-

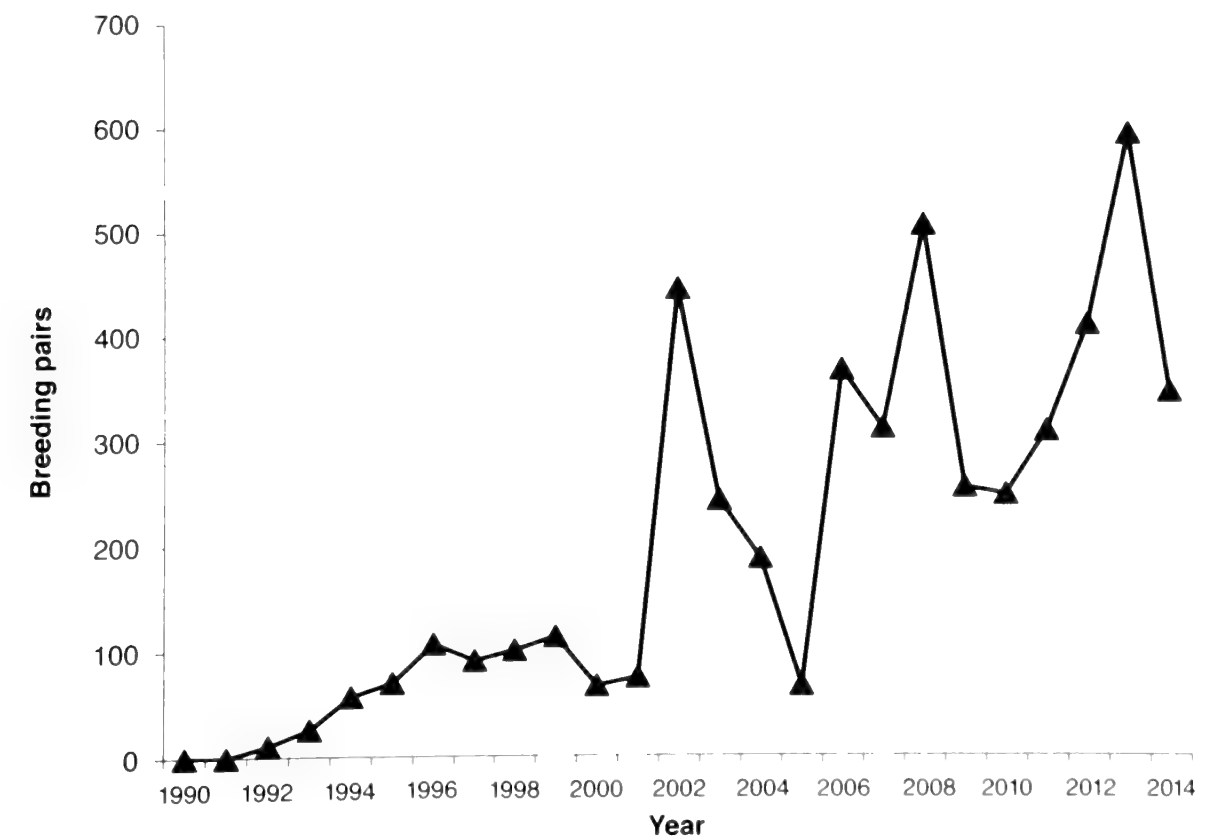


FIGURE 2. Estimated number of breeding Bufflehead (*Bucephala albeola*) pairs each May at Agassiz National Wildlife Refuge, based on 1990–2014 aerial-ground surveys.

mented, with Bufflehead breeding activity observed as far as 850 km south of their traditional breeding range (Richardson 2004).

The North American Bufflehead population trend shows an increasing overall population (1955–1992: Gauthier 2014) and a stable to increasing breeding population (1955–2010: Zimpfer *et al.* 2010; 1966–2010: Sauer *et al.* 2011). While the Bufflehead population in the boreal forests of Canada undergoes annual fluctuations, it has a stable long-term population trend (Fast *et al.* 2011).

There are several possible explanations for observing increased Bufflehead breeding activity in Minnesota as shown by the increased number of pairs and occurrences of potential breeding in new locations. Because Buffleheads nest in cavities and cavities can be a limiting factor, one possible explanation is that Buffleheads are finding more suitable nesting cavities along historical migratory routes. Aging trees or increases in the number of dead standing trees caused by flooding or insects could be involved.

In Minnesota, aspen stand ages may be reaching an appropriate diameter at breast height (DBH; Denton *et al.* 2012) for Northern Flickers to create more nesting cavities for Buffleheads. Martin *et al.* (2004) found Buffleheads using Trembling Aspen (*Populus tremuloides* Michaux) with an average DBH of 33 cm. The wet period recently experienced in the upper midwest and Great Plains (Millet *et al.* 2009) also could have increased the availability of dead standing trees near wetlands; warmer temperatures can facilitate the spread of pests such as beetles that may increase the amount of dead timber and cavities on the landscape (Dale *et al.* 2001).

Although aging or flooded or insect killed aspen stands may increase the number of potential breeding sites on a regional level, they do not entirely explain the southward expansion of the breeding range in California that likely is the result of a combination of factors (Richardson 2004). Hooded Mergansers (*Lophodytes cucullatus*), another cavity nesting species, appear to be expanding their breeding activity southward in California, likely as the result of an increasing population and available nesting cavities (Pandolfino *et al.* 2006). Increases in numbers of pairs and broods of this species have been documented at Agassiz NWR (USFWS, unpublished data, 1990–2014).

While many breeding bird ranges appear to be shifting northward (Whitaker 2017), Zuckerberg *et al.* (2009) found 43% of 129 avian species in New York state showed a southward shift in their mean breeding range latitude between 1980 and 2005. They found a shift of 34 km southward for Common Loons (*Gavia immer*), another boreal nesting, but not cavity-nesting, species.

Nest box programs could increase breeding opportunities for cavity-nesting ducks like Buffleheads. Even though a modest number of nest boxes (< 30) were erected on state Wildlife Management Areas adjacent

to Agassiz NWR by the Minnesota Department of Natural Resources around 2010, there has not been an active nest box program at Agassiz NWR since Bufflehead breeding activity was first documented at the refuge.

While habitat changes or shifts in breeding range are plausible explanations for increases in breeding activity observations for Buffleheads, some could be due to the increased ease and opportunity to report breeding activities. For example, eBird (eBird 2012) and several of the breeding bird state atlases (e.g., Minnesota) now have convenient ways for birders to report observations with detailed location and date information. As a result, some of the increased breeding observations across the United States could simply be an artifact of improved reporting and access to such reports rather than true range extensions or increases in breeding activity. However, the observations at Agassiz NWR appear to be increased activity, likely as the result of increased breeding success and suitable habitat available for Buffleheads given their high levels of natal philopatry.

Learning about the role of more southern latitude breeding sites could provide information on how Bufflehead populations are responding to climate, habitat changes, and even information about reporting of such observations. Furthermore, because limited research on Bufflehead has been conducted outside of British Columbia, Canada, studies are needed to understand habitat preferences in this newly utilized breeding range. In an era when many species are declining, it is important to understand factors contributing to stable or increasing populations.

Acknowledgements

Funding was provided by the University of North Dakota Biology Department, the University of North Dakota Senate Scholarly Activities Committee New Faculty Award, and the U.S. Fish and Wildlife Service. We thank Audubon Minnesota, Minnesota Department of Natural Resources, North American Breeding Bird Survey participants, Red Lake Watershed District, Middle-Snake-Tamarac River Watershed District, M. Anderson, B. Determan, J. B. Ellis, A. Hitt, A. Higgins, N. Janochoski, S. Lofgren, and J. Selchow for their assistance with Bufflehead pair and brood surveys, as well as numerous staff at Agassiz NWR who have assisted with duck production surveys over the past 22 years. We appreciate personal communications from B. Sample (Minnesota Audubon), and M. R. Fisher (U.S. Fish and Wildlife Service). In addition, we thank two anonymous reviewers and the associate editor (J. McCracken) and editor (D. A. W. Lepitzki) for valuable input that improved the manuscript. The findings and conclusions in this article are those of the author(s) and do not necessarily represent the views of the U.S. Fish and Wildlife Service. Data files associated with this project can be downloaded at: <http://und.edu/faculty/susan-felege/buffleheads.cfm>.

Literature Cited

- Bahls, J., and J. Bartholmai.** 2011. Bufflehead nesting in Wisconsin. *Wood Duck Newsgram* 63: 9–11.
- Dale, V. H., L. A. Joyce, S. McNulty, R. P. Neilson, M. P. Ayres, M. D. Flannigan, P. J. Hanson, L. C. Irland, A. E. Lugo, C. J. Peterson, D. Simberloff, F. J. Swanson, B. J. Stocks, and B. M. Wotton.** 2001. Climate change and forest disturbances. *BioScience* 51: 723–734. [https://doi.org/10.1641/0006-3568\(2001\)051\[0723:CCAFD\]2.0.CO;2](https://doi.org/10.1641/0006-3568(2001)051[0723:CCAFD]2.0.CO;2)
- Davis, G.** 1978. Bufflehead brood in Marshall County. *The Loon* 50: 213–214.
- Denton, J. C., C. L. Roy, G. J. Soulliere, and B. A. Potter.** 2012. Change in density of duck nest cavities at forests in the north central United States. *Journal of Fish and Wildlife Management* 3: 76–88. <https://doi.org/10.3996/112011-JFWM-067>
- eBird.** 2012. eBird: An online database of bird distribution and abundance. eBird, Cornell Lab of Ornithology, Ithaca, New York, USA. Accessed 21 September 2017. <http://www.ebird.org>.
- Erskine, A. J.** 1972. Buffleheads. Canadian Wildlife Service Monograph Series (4). Information Canada, Ottawa, Ontario, Canada.
- Fast, M., B. Collins, and M. Gendron.** 2011. Trends in breeding waterfowl in Canada. Canadian biodiversity: ecosystem status and trends 2010, technical thematic report no. 8. Canadian Councils of Resource Ministers. Ottawa, Ontario, Canada. Accessed 21 September 2017. <http://www.biodivcanada.ca/default.asp?lang=En&n=9F45F292-1>.
- Floyd, T., C. S. Elphick, G. Chisholm, K. Mack, R. G. Elston, E. M. Ammon, and J. D. Boone.** 2007. Atlas of the Breeding Birds of Nevada. University of Nevada Press, Reno, Nevada, USA.
- Gollop, J. B., and W. H. Marshall.** 1954. A guide for aging duck broods in the field. Mississippi Flyway Council Technical Section. Northern Prairie Wildlife Research Center Online. Accessed 7 October 2017. <http://archive.is/fpqWk>.
- Gauthier, G.** 1988. Factors affecting nest-box use by Buffleheads and other cavity-nesting birds. *Wildlife Society Bulletin* 16: 132–141.
- Gauthier, G.** 2014. Bufflehead (*Bucephala albeola*). In *The Birds of North America*. Edited by P. G. Rodewald. Cornell Lab of Ornithology, Ithaca, New York, USA. Accessed 21 September 2017. <https://birdsna.org/Species-Account/bna/species/buffle>.
- Giudice, J. H.** 2001. Visibility bias in waterfowl brood surveys and population ecology of dabbling ducks in central Washington. Ph.D. thesis, University of Idaho, Moscow, Idaho, USA.
- Hammond, M. C.** 1969. Notes on conducting waterfowl breeding pair surveys. Pages 238–258 in *Saskatoon wetlands seminar*. Canadian Wildlife Service report series 6, Environment Canada, Ottawa, Ontario, Canada.
- Heidel, K.** 1983. Bufflehead and ducklings found in Carver Park Reserve. *The Loon* 55: 123–124.
- Janssen, R. B.** 1987. Birds in Minnesota. University of Minnesota Press for the James Ford Bell Museum of Natural History, Minneapolis, Minnesota, USA.
- Knutsen, G. A., and J. C. King.** 2004. Bufflehead breeding activity in south-central North Dakota. *Prairie Naturalist* 36: 187–190.
- Martin, K., K. E. H. Aitken, and K. L. Wiebe.** 2004. Nest sites and nest webs for cavity-nesting communities in interior British Columbia, Canada: nest characteristics and niche partitioning. *Condor* 106: 5–19. <http://doi.org/10.1650/7482>
- MacKenzie, D. I., J. Nichols, J. Royle, K. Pollock, J. E. Hines, and L. L. Bailey.** 2006. Occupancy Estimation and Modeling: Inferring Patterns and Dynamics of Species. Academic Press, Burlington, Massachusetts, USA.
- Mattsson, J.** 1986. Another Bufflehead brood at Agassiz NWR. *The Loon* 58: 140.
- Millet, B., W. C. Johnson, and G. Guntenspergen.** 2009. Climate trends of the North American prairie pothole region 1906–2000. *Climatic Change* 93: 243–267. <https://doi.org/10.1007/s10584-008-9543-5>
- Pandolfino, E. R., J. Kwolek, and K. Kreitinger.** 2006. Expansion of the breeding range of the Hooded Merganser within California. *Western Birds* 37: 228–236.
- Pardieck, K. L., D. J. Ziolkowski, Jr., M.-A. R. Hudson, and K. Campbell.** 2016. North American Breeding Bird Survey Dataset 1966–2015, version 2015.1. U.S. Geological Survey, Patuxent Wildlife Research Center. <https://doi.org/10.5066/F7C53HZN>
- Pfannmuller, L., G. Niemi, J. Green, B. Sample, N. Walton, E. Zlonis, T. Brown, A. Brace, G. Host, J. Reed, K. Rewinkel, and N. Will.** 2017. Minnesota Breeding Bird Atlas (2009–2013). Accessed 13 March 2018. <https://mnbirdatlas.org/species/bufflehead>.
- Richardson, T. W.** 2004. Expansion of the breeding range of the Bufflehead in California. *Western Birds* 35: 168–172.
- Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski, Jr., and W. A. Link.** 2011. The North American Breeding Bird Survey, results and analysis 1966–2010. Version 12.07.2011. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.
- USFWS (U.S. Fish and Wildlife Service).** 1978. Agassiz National Wildlife Refuge, master plan. U.S. Department of the Interior, Fish and Wildlife Service, Middle River, Minnesota, USA.
- USFWS (U.S. Fish and Wildlife Service).** 2005. Agassiz National Wildlife Refuge, comprehensive conservation plan. U.S. Department of the Interior, Fish and Wildlife Service, Middle River, Minnesota, USA.
- USFWS (U.S. Fish and Wildlife Service).** 2008. Agassiz National Wildlife Refuge wildlife inventory and monitoring plan. U.S. Department of the Interior, Fish and Wildlife Service, Middle River, Minnesota, USA.
- Whitaker, D.** 2017. Expanded range limits of boreal birds in the Torngat Mountains of Northern Labrador. *Canadian Field-Naturalist* 131: 55–62. <https://doi.org/10.22621/cfn.v131i1.1957>
- Whitt, M. B.** 1999. Bufflehead brood in northeastern South Dakota. *Prairie Naturalist* 31: 119–120.
- Zimpfer, N., W. Rhodes, E. D. Silverman, G. Zimmerman, and M. D. Koneff.** 2010. Trends in duck breeding populations, 1955–2010. U.S. Fish and Wildlife Service Publication 417, Laurel, Maryland, USA.
- Zuckerberg, B., A. M. Woods, and W. F. Porter.** 2009. Poleward shifts in breeding bird distributions in New York State. *Global Change Biology* 15: 1866–1883. <https://doi.org/10.1111/j.1365-2486.2009.01878.x>

Received 25 June 2017

Accepted 4 January 2018

New Breeding Record for Merlin (*Falco columbarius*) in Southwestern Yukon

RYAN P. LAMOUREUX^{1,2}, MELANIE R. BOUDREAU¹, and JACOB L. SEGUIN¹

¹Environmental and Life Sciences, Trent University, Peterborough, Ontario K9J 0G2 Canada

²Corresponding author: ryanlamoureux@trentu.ca

Lamoureux, Ryan P., Melanie R. Boudreau, and Jacob L. Seguin. 2017. New breeding record for Merlin (*Falco columbarius*) in southwestern Yukon. *Canadian Field-Naturalist* 131(4): 344–346. <https://doi.org/10.22621/cfn.v131i4.1910>

On 3 May 2016, we observed two Merlins (*Falco columbarius*) copulating near Hungry Lake in southwestern Yukon. We recorded Merlins frequently from May until the beginning of July and observed them defending the area from Common Ravens (*Corvus corax*) on two occasions, an activity indicative of a nesting pair. This is the first breeding record for Merlins in southern Yukon, as previous records have documented the breeding range only in central and northern parts of the territory. Here, we summarize historical sightings and breeding reports throughout southern Yukon since 1975 and fill a gap in the breeding range of this species.

Key Words: Merlin; *Falco columbarius*; breeding range; Kluane National Park; Yukon

Introduction

Merlins (*Falco columbarius*) have a wide distribution, ranging from northern Peru to the northern treeline in Alaska and Canada (Warkentin *et al.* 2005). Although Merlins are relatively uncommon in Yukon (Sinclair *et al.* 2003), they have been documented breeding in the Richardson and Ogilvie Mountains of central Yukon and in the British Mountains, as well as along the Porcupine River and Old Crow Flats in northern Yukon (Sinclair *et al.* 2003). While they are suspected of nesting in southern Yukon based on signs of aggressive behaviour, nesting has not yet been documented there (Sinclair *et al.* 2003; eBird 2017).

Merlins are habitat generalists, preferring fairly open country, such as willow (*Salix* spp.) or birch (*Betula* spp.) scrub and shrubland, as well as taiga forest, moorland, and grasslands, such as steppe and prairies (White 1994). Merlins generally inhabit ecosystems that have a mix of low and medium-height vegetation with interspersed trees and avoid dense forests as well as treeless arid regions (White 1994). Within their breeding range, they are found in open to semi-open habitat, often nesting in forest openings, fragmented woodlots, and near rivers, lakes, or bogs (Warkentin *et al.* 2005).

Merlins do not create nests of their own, but rather use abandoned nests (of corvids or hawks) in conifer or mixed tree stands (Sieg and Becker 1990; White 1994). Nests are rarely found in tree cavities, on cliffs, or on the ground (Bent 1938; Fox 1964), but are often highly concealed from predators by conifers (Warkentin and James 1988; Sieg and Becker 1990). In Yukon, breeding pairs are often associated with riverside cliffs or trees; they start arriving in mid-April and initiate nesting by the end of May (Sinclair *et al.* 2003).

Here, we report the first record of breeding Merlins in southern Yukon.

Observations

On 3 May 2016, we photographed (Figure 1) two Merlins copulating (60.9824°N, 138.1372°W), 1 km east of Hungry Lake in southwestern Yukon, near Kluane National Park. The pair occupied an area with vegetation cover dominated by White Spruce (*Picea glauca* (Moench) Voss), Grey Willow (*Salix glauca* L.), and Bog Birch (*Betula glandulosa* Michaux). Historical pipeline trails offer 10-m wide strips without a dense spruce canopy. Between 3 May and 1 July, we spent 36 mornings in the area and recorded the Merlins frequently, including two occasions on which we observed them defending the area from Common Ravens (*Corvus corax*), as indicated by aerial chase, dives, and loud calls.

We searched eBird, a citizen science database of bird observations, for all recorded Merlin sightings from 1975 to 2016 during the breeding season (April–August; eBird 2017). There were 19 records of Merlins within approximately 20 km of our location: one in April (1975), three in June (1990, 2002, 2016), and the other 15 in August. There were no records from May, during the peak egg-laying and incubation period, or July, when young are still in the nest and are typically highly vocal. Of the 19 reported sightings in southwestern Yukon, only one was of a pair, observed on the Sheep Mountain Trail (approximately 22 km northwest of our observed breeding site). Of the 606 sightings across southern Yukon during the breeding seasons from 1975–2016, only 7% reported two Merlin and none indicate a breeding pair was observed (eBird 2017).

Discussion

Although Merlins are relatively uncommon in Yukon, nesting has been documented in the northern and central portions of the territory, but not in the south (Sinclair *et al.* 2003; eBird 2017). We were unable to locate the

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalists' Club.



FIGURE 1. (a) A female Merlin (*Falco columbarius*) photographed at 0923 and (b) a male Merlin (*Falco columbarius*) copulating with a female Merlin at 0925. Both photographs were taken near Hungry Lake, southwestern Yukon (60.9824°N, 138.1372°W) on 3 May 2016. Photos: R. P. Lamoureux.

Merlins' nest, but copulation and defense against corvids by both males and females is a reliable indicator of a nearby nest site (Sodhi 1991; Sodhi *et al.* 1992), typically within 800 m (Hardey *et al.* 2006). In addition, the landscape surrounding the observed Merlins included a small pond just over 350 m from the point of copulation, as well as two larger lakes, Hungry Lake and Thirsty Lake, approximately 1 and 1.3 km away, respectively. Both lakes have steep sand embankments over 40 m in height and the surrounding area is dominated by White Spruce with willow and birch understorey (Krebs *et al.* 2001). Our observations are consistent with known nesting habitat characteristics and nesting behaviour of Merlins (White 1994; Warkentin *et al.* 2005; Sinclair *et al.* 2003).

Our documentation of copulation, coupled with a habitat seemingly suitable for nesting, provides evidence for the first breeding record of the Merlin in southern Yukon. Whether this represents range expansion for nesting Merlins or, alternatively, is a function of low sampling effort for the species in southern Yukon compared with other parts of their range is unknown. Although we cannot confirm nesting, the evidence suggests that the southern Yukon may be more suitable for Merlin breeding than previously indicated by breeding records and may show that current knowledge of breeding range for this species is limited.

Acknowledgements

We thank the Champagne and Aishihik First Nation and Kluane First Nation for allowing us to work in their traditional territory. In addition, we thank Scott Flemming, Justin Johnson, Marcel Gahbauer, and an anonymous reviewer for their editorial contributions.

Literature Cited

- Bent, A. C. 1938. Life Histories of North American Birds of Prey (Part 2). Orders Falconiformes and Strigiformes. Bulletin of the United States Natural Museum 170. Smithsonian Institution, Washington, DC, USA. <https://doi.org/10.5479/si.03629236.170.i>
- eBird. 2017. eBird: an online database of bird distribution and abundance. Audubon and Cornell Lab of Ornithology, Ithaca, New York, USA. Accessed January 2017. <https://tinyurl.com/y7k8gupd>.
- Fox, G. A. 1964. Notes on the western race of the Pigeon Hawk. Blue Jay 22: 140–147.
- Hardey, J., H. Q. P. Crick, C. V. Wernham, H. T. Riley, B. Ethridge, and D. B. A. Thompson. 2006. Merlin, *Falco columbarius*. In *Raptors: A Field Guide to Survey and Monitoring*. Stationery Office, Edinburgh, Scotland.
- Krebs, C. J., S. Boutin, and R. Boonstra. 2001. *Ecosystem Dynamics of the Boreal Forest: The Kluane Project*. Oxford University Press, New York, New York, USA.
- Sieg, C. H., and D. M. Becker. 1990. Nest-site habitat selected by Merlins in southeastern Montana. Condor 92: 688–694. <https://doi.org/10.2307/1368687>

- Sinclair, P. H., W. A. Nixon, C. D. Eckert, and N. L. Hughes.** 2003. Birds of the Yukon Territory. UBC Press, Vancouver, British Columbia, Canada. <https://doi.org/10.1086/382423>
- Sodhi, N. S.** 1991. Pair copulations, extra-pair copulations, and intraspecific nest intrusions in Merlin. *Condor* 93: 434–437. <https://doi.org/10.2307/1368960>
- Sodhi, N. S., P. C. James, I. G. Warkentin, and L. W. Oliphant.** 1992. Breeding ecology of urban Merlins (*Falco columbarius*). *Canadian Journal of Zoology* 70: 1477–1483. <https://doi.org/10.1139/z92-204>
- Warkentin, I. G., N. S. Sodhi, R. H. M. Espie, A. F. Poole, L. W. Oliphant, and P. C. James.** 2005. Merlin (*Falco columbarius*). In *The Birds of North America Online*. Edited by P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. <https://doi.org/10.2173/bna.44>
- Warkentin, I. G., and P. C. James.** 1988. Nest-site selection by urban Merlins. *Condor* 90: 734–738. <https://doi.org/10.2307/1368372>
- White, C. M.** 1994. Merlin. Page 267 and plate 27 in *Handbook of Birds of the World. Volume 2: New World Vultures to Guinea fowl*. Edited by J. Del Hoyo, J. Sargatal, and A. Elliot. Lynx Editions, Barcelona, Spain.

Received 23 February 2017

Accepted 4 January 2018

Note

Evidence for a Negative Effect of Double-crested Cormorants (*Phalacrocorax auritus*) on Invasive European Fire Ants (*Myrmica rubra*)

ADITI GUPTA¹, KRISTI RUDMIK¹, and GAIL S. FRASER^{1,2}

¹Faculty of Environmental Studies, York University, Toronto, Ontario M3J 1P3 Canada

²Corresponding author: gfraser@yorku.ca

Gupta, Aditi, Kristi Rudmik, and Gail S. Fraser. 2017. Evidence for a negative effect of Double-crested Cormorants (*Phalacrocorax auritus*) on invasive European Fire Ants (*Myrmica rubra*). *Canadian Field-Naturalist* 131(4): 347–349. <https://doi.org/10.22621/cfn.v131i4.1845>

Nesting of Double-crested Cormorants (*Phalacrocorax auritus*) in western Lake Ontario is associated with reduced abundance and nest density of European Fire Ants (*Myrmica rubra*). The impact on fire ants may be substrate related. It is of potential importance because of the negative effect of fire ants on ground-nesting water birds.

Key Words: Double-crested Cormorant; *Phalacrocorax auritus*; European Fire Ant; *Myrmica rubra*; invasive species; ant nest density; non-native; guano; soil

The invasive European Fire Ant (*Myrmica rubra*) is established in many regions of North America (Wetterer and Radchenko 2011). Locally, its abundance and distribution are influenced by soil moisture and temperature: it prefers moist soils shaded by vegetation (Grodén *et al.* 2005). North American populations may be unusually abundant, and nest densities may be high (Grodén *et al.* 2005; Naumann and Higgins 2015). Infestations can have long-term consequences for ground-nesting birds, such as Herring Gulls (*Larus argentatus*; DeFisher and Bonter 2013).

Double-crested Cormorant (*Phalacrocorax auritus*) is a water bird, native to North America (Dorr *et al.* 2014), whose numbers have increased greatly in parts of the Great Lakes region over the past few decades. At high densities, tree-nesting cormorants alter soil chemistry, reducing plant ground cover and species richness (Weseloh *et al.* 2002) as well as arthropod diversity (Craig *et al.* 2012); however, these changes can also provide habitat for ground-nesting birds (e.g., Foster and Fraser 2013). When trees fall, cormorants move to adjacent forest, eventually killing the next set of trees, or they nest on the ground (McGrath and Murphy 2012). In this study, we examined how cormorant-induced forest alterations affected fire ant abundance, distribution, and nest density in a protected area.

Created in the 1970s as the Leslie Street Spit, Tommy Thompson Park (TTP) is a human-made headland extending 5 km into Lake Ontario. In 1990, cormorants started nesting there and have caused deforestation on three of the four peninsulas (Taylor *et al.* 2011). In 2015, peninsula C (43°37'37.80"N, 79°20'15.10"W) had 2561 cormorant nests in trees (22% of the 11 908 cormorant nests at TTP; Toronto and Region Conservation Authority, unpublished data; see also Taylor *et al.* 2011). It is unknown when fire ants first colonized TTP.

In August 2010 and 2015, we examined ant abundance and nest density at 12 stations located 50 m apart along a 550-m transect through the cormorant colony

on peninsula C. At each station, five pitfall traps were placed flush with the ground, half filled with salted distilled water containing a drop of unscented detergent, and left out for 48 h. Four species of ants, identified using Fisher and Cover (2007), were collected, dried, and weighed. Because of their great abundance at some stations, the number of European Fire Ants per station was estimated from the average weight of a randomly selected subsample of dried and counted ants across stations: 200 ants in 2010, 150 in 2015. We also measured ant nest density (Grodén *et al.* 2005) and estimated percentage plant ground cover (Elzinga *et al.* 1998) in a 1-m² quadrat 10 m east of each station.

The transect crossed three habitats: field (open with few or no trees mostly covered in grass and forbs), healthy forest (trees alive, strong under-canopy foliage), and dying forest (trees dead or in poor condition and little understorey). Two general linear models and *post hoc* Tukey tests (Minitab 17.1.0) were used to evaluate changes in 1) ant abundance and 2) plant ground cover (both log-transformed; Zar 2010) for year and habitat type. Ant nest density was not included in the models because no nests were observed in field and dying forests (see below). Differences in ant nest density between the two study years in healthy forests were evaluated using a Mann–Whitney *U* test (Zar 2010).

Between 2010 and 2015, four stations changed habitat categories: one from healthy to dying forest (station E) and three from dying forest to field (stations A–C). At stations A–C, ground cover increased in 2015 (primarily Stinging Nettle [*Urtica dioica* L.]). Ground cover varied by habitat type, but not by year. Dying forest had significantly less ground cover compared with field and healthy forest, and there was no significant difference between the latter two categories (Table 1). Means ± standard deviation (SD) were: dying forest 3.3% ± 2.6%, field 88.9% ± 8.9%, healthy forest 88.9% ± 22.5%.

TABLE 1. Habitat characterization, ground cover, and abundance of European Fire Ants (*Myrmica rubra*) at sampling stations under Double-crested Cormorant (*Phalacrocorax auritus*) nests in Tommy Thompson Park, Toronto, Ontario, 2010 and 2015.

Station	Habitat characterization*		Ground cover†, %		Total ant abundance in five traps‡	
	2010	2015	2010	2015	2010	2015
A	DF	Field	5	80	0.0	16.0
B	DF	Field	5	80	0.0	16.0
C	DF	Field	0	90	0.0	0.0
D	DF	DF	5	5	0.0	0.0
E	HF	DF	100	0	2524.8	8.0
F	HF	HF	100	95	4915.7	13 476.0
G	HF	HF	90	90	8797.7	7812.0
H	HF	HF	30	95	8036.9	17 359.5
I	HF	HF	100	100	4927.1	3061.5
J	Field	Field	80	80	234.0	3711.0
K	Field	Field	95	95	0.0	0.0
L	Field	Field	100	100	0.0	0.0

*DF = dead and dying forest, HF = healthy forest. Cormorants nested at stations A, B, C, and D in 2010 and at stations D and E in 2015.

†Ground cover varied by habitat type, but not by year (habitat: $F_{2,23} = 62.2, P < 0.0001$; year: $F_{1,23} = 0.07, P = 0.78$). Field and healthy forest did not differ in % ground cover, but both habitats differed from dying forest (Tukey pairwise comparison, $P < 0.05$).

‡Fire ant abundance differed by habitat type, but not by year (habitat: $F_{2,23} = 38.2, P < 0.0001$; year: $F_{1,23} = 0.6, P = 0.42$). Healthy forest differed in ant abundance compared with dying forest and field (Tukey pairwise comparison, $P < 0.05$).

Fire ant abundance differed by habitat type, but not by year; ant abundance was higher in healthy forest compared with field and dying forest (Table 1). Based on the 1-m² quadrat samples, no fire ant nests were observed in field or dying forest, and there was no difference in ant nest density in healthy forest between study years (mean ± SD): 2010 ($n = 6$) 1.2 ± 1.8 nests/m², 2015 ($n = 5$) 0.2 ± 0.4 nests/m² (Mann–Whitney $U = 39.0, P > 0.2$). At station E, which changed to dying forest, a substantial decline in fire ant abundance and ant nest density occurred (from three nests to zero; Table 1).

The presence of nesting cormorants appears to have a negative effect on fire ant abundance. The relatively low numbers of fire ants in forest declining because of cormorant nesting and the clear decrease in fire ant abundance and ant nest density at one station where cormorant nesting led to forest decline suggest that soil changes associated with cormorants may reduce suitability for fire ant habitation. This is of interest because other ground-nesting water birds occupying deforested areas may benefit from reducing or eliminating fire ants (see DeFisher and Bonter 2013). Future deliberations on cormorant management (e.g., Wires 2014 describes and critiques North American cormorant management) should consider the potentially positive impact of nesting cormorants on reducing fire ant infestations where the two species co-occur.

Acknowledgements

We thank the Toronto and Region Conservation Authority, L. Packer, L. Molot, and P. Mojdehi for logistical support; E. Ali, S. Conliffe, and M. Tompkins for field assistance; J. Podur and M. Tompkins for sta-

tistical advice; and L. Packer, P. Catling, and two anonymous reviewers for comments on this manuscript.

Literature Cited

Craig, C. E., B. S. Elbin, A. J. Danoff-Burg, and I. P. Palmer. 2012. Impacts of Double-Crested Cormorants and other colonial waterbirds on plants and arthropod communities on islands in an urban estuary. *Waterbirds* 35: 4–12. <https://doi.org/10.1675/063.035.sp102>

DeFisher, L. E., and D. N. Bonter. 2013. Effects of invasive European Fire Ants (*Myrmica rubra*) on Herring Gull (*Larus argentatus*) reproduction. *PLoS ONE* 8(5): e64185. <https://doi.org/10.1371/journal.pone.0064185>

Dorr, B. S., J. J. Hatch, and D. V. Weseloh. 2014. Double-crested Cormorant (*Phalacrocorax auritus*). In *The Birds of North America*. Edited by P. G. Rodewald. Cornell Lab of Ornithology, Ithaca, New York, USA. <https://doi.org/10.2173/bna.441>

Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. Measuring and monitoring plant populations. Technical reference 1730-1. Bureau of Land Management, U.S. Department of the Interior, Denver, Colorado, USA. Accessed 23 June 2017. <https://www.blm.gov/nstc/library/pdf/MeasAndMon.pdf>

Fisher, B. L., and S. P. Cover. 2007. *Ants of North America: A Guide to the Genera*. University of California Press, Oakland, California, USA.

Foster, J., and G. S. Fraser. 2013. Predators, prey and the dynamics of change at the Leslie Street Spit. Pages 211–224 in *Urban Explorations: Environmental Histories of the Toronto Region*. Edited by L. A. Sandberg, S. Bocking, C. Coates, and K. Cruikshank. L. R. Wilson Institute for Canadian Studies, Hamilton, Ontario, Canada.

Groden, E., F. A. Drummond, J. Garnas, and A. Franceour. 2005. Distribution of an invasive ant, *Myrmica rubra* (Hymenoptera: Formicidae), in Maine. *Journal of Economic*

Entomology 98: 1774–1784. <https://doi.org/10.1093/jee/98.6.1774>

McGrath, M. D., and D. S. Murphy. 2012. Double-crested Cormorant (*Phalacrocorax auritus*) nesting effects on understory composition and diversity on island ecosystems in Lake Erie. *Environmental Management* 50: 304–314. <https://doi.org/10.1007/s00267-012-9878-6>

Naumann, K., and R. J. Higgins. 2015. The European Fire Ant (Hymenoptera: Formicidae) as an invasive species: impact on local ant species and other epigeic arthropods. *Canadian Entomology* 174: 592–601. <https://doi.org/10.4039/ce.2014.69>

Taylor, B., D. Andrews, and G. S. Fraser. 2011. Double-crested cormorants and urban wilderness: conflicts and management. *Urban Ecosystems* 14: 377–394. <https://doi.org/10.1007/s11252-011-0165-8>

Weseloh, D. V. C., C. Pekarik, T. Havelka, G. Barrett, and J. Reid. 2002. Population trends and colony locations of double-crested cormorants in the Canadian Great lakes and immediately adjacent areas, 1990–2000: a manager's guide. *Journal of Great Lakes Research* 28: 125–144. [https://doi.org/10.1016/S0380-1330\(02\)70571-6](https://doi.org/10.1016/S0380-1330(02)70571-6)

Wetterer, J. K., and A. G. Radchenko. 2011. Worldwide spread of the ruby ant, *Myrmica rubra* (Hymenoptera: Formicidae). *Myrmecological News* 14: 87–96.

Wires, L. R. 2014. *The Double-crested Cormorant: Plight of a Feathered Pariah*. Yale University Press, New Haven, Connecticut, USA.

Zar, J. H. 2010. *Biostatistical Analysis* (Fifth Edition). Pearson Prentice-Hall, Upper Saddle River, New Jersey, USA.

Received 17 August 2016
Accepted 23 February 2018

Diverse Ecological Pathways of Salmon Nutrients Through an Intact Marine-terrestrial Interface

THOMAS E. REIMCHEN

Department of Biology, University of Victoria, P.O. Box 3020, Victoria, British Columbia V8W 3N5 Canada; email: reimchen@uvic.ca

Reimchen, Thomas E. 2017. Diverse ecological pathways of salmon nutrients through an intact marine-terrestrial interface. *Canadian Field-Naturalist* 131(4): 350–368. <https://doi.org/10.22621/cfn.v131i4.1965>

Based on five years of field studies (1992, 1993, 1994, 1998, 2000), I quantified bi-directional movement of salmon nutrients through an estuary, stream, and old growth forest in a large protected reserve on Haida Gwaii, British Columbia. In 1993, when most data were collected, about 6000 Chum Salmon (*Oncorhynchus keta*) entered the river of which 22% of the total biomass of senescent carcasses were swept downstream into the estuary and were scavenged by gulls ($n = 350$) and subtidal invertebrates. Of the 3700 salmon (10 000 kg) transferred by American Black Bear (*Ursus americanus*) to the riparian zone and partially consumed along the 800 m of stream channel, 5070 kg of salmon tissues abandoned by the bears were scavenged by Northwestern Crows (*Corvus caurinus*; $n = 200$) but mostly (4100 kg) by calliphorid blowfly larvae resulting in larval densities averaging 240/m² throughout the riparian zone. Total nitrogen input to the soils from the combined effects of bear and scavenger activity as well as carcass input was 18 g/m² within 10 m of the stream channel. $\delta^{15}\text{N}$ of foliar tissues of Lanky Moss (*Rhytidiadelphus loreus*), Red Huckleberry (*Vaccinium parvifolium*), Salal (*Gaultheria shallon*), and Western Hemlock (*Tsuga heterophylla*) ranged about 15‰ to 20‰ among adjacent microsites in each species, with higher values occurring in salmon carcass zones. Total nitrogen in foliar tissues ranged from 1% to 2.4% among microsites and was best predicted by positive correlations with foliar ^{15}N values and secondarily by presence/absence of salmon carcasses. This is the first study to integrate estuarine to riparian ecological processes in the cycling of salmonid nutrients and identifies a range of ecological baselines that can inform the multiple restoration programs underway in degraded watersheds in the North Pacific.

Key Words: Ancient forest; Calliphoridae; *Corvus*; ecological baselines; energy flow; Haida Gwaii; *Larus*; *Oncorhynchus*; spawning migration; *Ursus*

Introduction

A dominant cross-boundary subsidy at the marine-terrestrial interface in the North Pacific is the yearly migration of adult salmon (*Oncorhynchus* spp.) to their natal spawning rivers. The importance of these migrations is widely recognized, not only for the marine predators and scavengers that aggregate in coastal and inshore waters (summaries in Willson and Halupka 1995; Cederholm *et al.* 1999, 2000; Hilderbrand *et al.* 2004), but also for terrestrial predators such as bears that disperse from higher elevation or inland areas to rivers and estuaries (Gilbert and Lanner 1995; Hilderbrand *et al.* 1996; Reimchen 2000; Gende *et al.* 2004). Historical records of salmon show declining biomass throughout the coast, particularly in southern watersheds (California, Oregon, Washington) where up to 95% of the salmon biomass has been lost over the last 100 years (Gresh *et al.* 2000). Presumably, this loss has negatively influenced the taxa that were trophically coupled to salmon biomass. While this is a reasonable inference for taxa such as bears (Gilbert and Lanner 1995), the influences on other consumers are unknown. This data deficiency emerges in part because the empirical partitioning of salmon biomass by multiple predator and scavenger taxa has not been described for any watershed and estuary in the North Pacific. Identifying such data in an intact marine-terrestrial food web would be useful not

only for assessing basic trophic interactions among species but also for evaluating the potential impact of the historical decline in abundance of salmon.

The southern end of the Haida Gwaii archipelago, 100 km off the west coast of Canada, is a largely intact ecosystem with old growth forest and numerous small streams, most with spawning runs of Chum Salmon (*Oncorhynchus keta*) or Pink Salmon (*O. gorbuscha*). Salmon have declined in these watersheds and are approximately at 50% of the decadal averages observed during the 1940s and 1950s when yearly records were initiated (Marshall *et al.* 1978; Reimchen 2000). During autumn 1992, 1993, and 1994, I quantified predator and scavenger use of adult salmon in the estuary, stream, and riparian zones at Bag Harbour, one of the typical watersheds in the region. Several novel observations emerged during this early study, including the frequent nocturnal foraging by American Black Bear (*Ursus americanus*; Reimchen 1998) and their high transfer rate of salmon carcasses from the stream to the riparian zone (Reimchen 2000). This bear-mediated uploading of salmon had positive effects on annual growth of Sitka Spruce (*Picea sitchensis* (Bongard) Carrière), which was greater in microsites where carcasses were prevalent and greater during years when spawning runs were elevated (Reimchen and Fox 2013). In the current manuscript, I estimate the total mass of salmon used by

each of the major mammalian, avian, and invertebrate foragers for the estuary, stream, and riparian habitats, estimate the total input of nitrogen into riparian soils, quantify the extent of enrichment of the marine-derived nitrogen (^{15}N) in riparian plants, and examine foliar ^{15}N as a proxy for primary productivity across a spatial gradient of carcasses and bear activity.

Methods

Bag Harbour (52.347°N, 131.366°W) occurs in a mountainous area on Moresby Island near the south end of Haida Gwaii (Figure 1). The small shallow harbour (33 ha, maximum depth ~16 m) has a broad intertidal zone with extensive cover of macrophytes (*Fucus* spp.) and lower intertidal and subtidal beds of eel grass (*Zosteraceae*). The harbour is bordered by ancient forest dominated by Sitka Spruce, Western Hemlock (*Tsuga heterophylla* (Rafinesque) Sargent), and Red Cedar (*Thuja plicata* Donn ex D. Don) with trees reaching 1000 years of age (Reimchen and Fox 2013) and classified as a very wet hypermaritime subzone 3 (CWHvh3 Site Series 110; Banner *et al.* 2014). There is a single major salmon-bearing stream (5–10 m width, < 0.5 m

depth, ~1° gradient) which extends 1500 m between the estuary and a small headwater lake. Most of the spawning gravels are found from 300 to 800 m up-stream from the estuary. Between 2300 and 6300 salmon enter the stream yearly, the majority (~90%) of which are Chum Salmon with additional Pink Salmon, and Coho Salmon (*O. keta*), the latter using tributary streams to the headwater lake. Field surveys were initially made in 1992 during the second half of the salmon spawning period (8–21 October) and in 1993 throughout the spawning period (28 September–26 October) with a supplemental survey two weeks after completion of the spawning run (13–14 November). In 1994, I made carcass counts midway through the spawning run (12–13 October) and near the end of the run (2–4 November). The site was also visited in 1998 (10–11 October) and again in 2000 (19–20 September). Additional details are given in Reimchen (1998, 2000) and Reimchen and Fox (2013). In 1992 and 1993, the major mammalian and avian foragers and scavengers were counted daily in early morning, mid-day, and late afternoon. Intermittently throughout the day, I recorded general predator and scavenging forag-

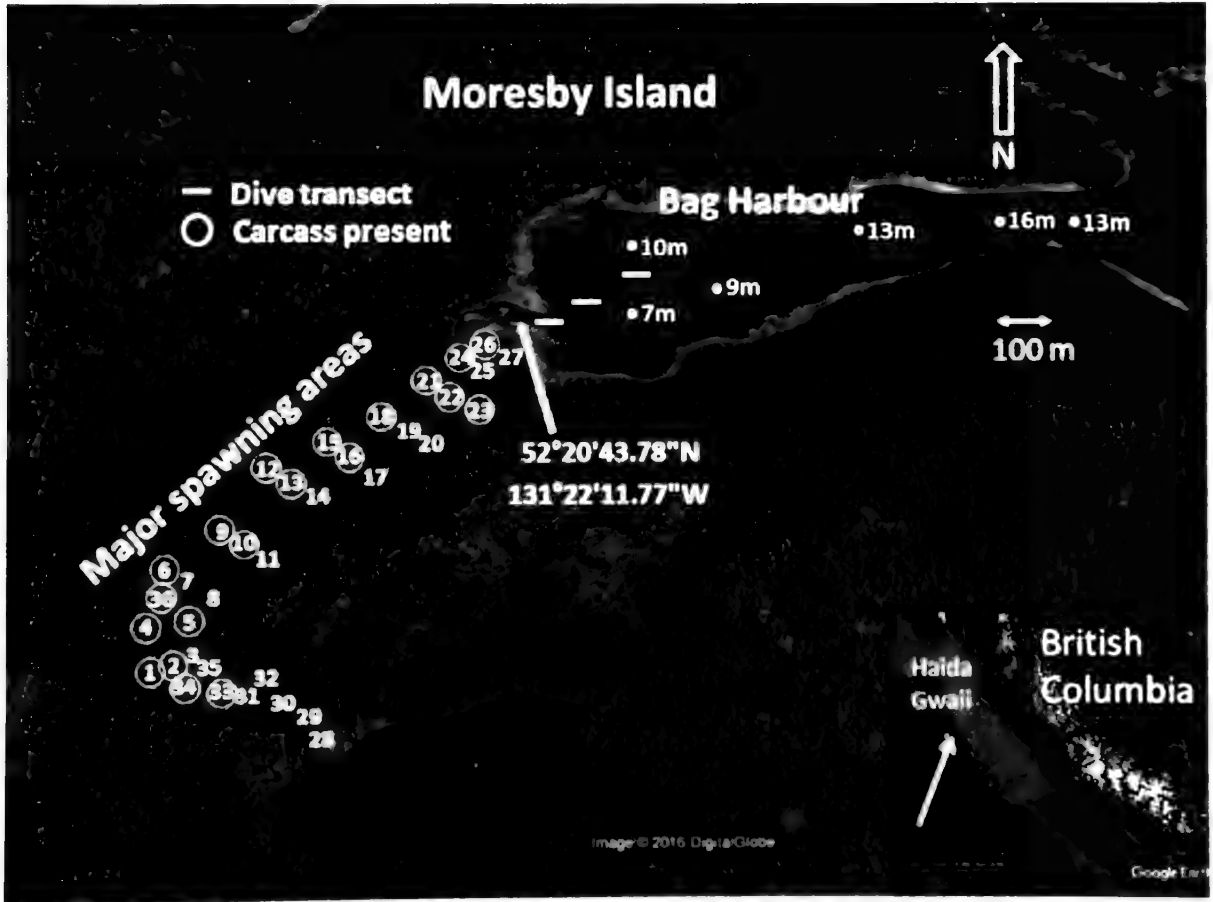


FIGURE 1. Bag Harbour, British Columbia study area. Microsites (#1–35) for plant samples (2000). Circled microsites had Chum Salmon (*Oncorhynchus keta*) carcasses. Horizontal bars in estuary are sites of three SCUBA transects (1993). Water depth (closed circle) shown in meters (m). Source: Bag Harbour, Moresby Island, 52.2043.78°N, 131.2211.77°W (Google Earth, Imagery date: 6 September 2016, Accessed: 1 March 2017).

ing activity of each focal species and, where possible, type of tissues consumed (fresh salmon, senescent carcasses, eggs). Fungal and bacterial decomposers as well as stream macroinvertebrates were present on some carcasses, but the extent of their carcass use was not quantified. Songbirds, rodents, and shrews, although present in the watershed, were not commonly seen during the autumn surveys and were not quantified. In 1993, observations were extended throughout the night using helmet-mounted night-viewing goggles (Reimchen 1998). In October 1993, 40 undamaged salmon carcasses collected from the stream were measured for individual mass (± 10 g) and tethered every 3.4 m along each of three subtidal rope transects at 10 m, 75 m, and 150 m distance from the stream mouth at depths increasing from 3 m to 10 m (Figure 1). Every 24 hours over the following seven days, I used SCUBA to survey each of the carcasses and recorded numbers of the dominant marine scavengers on the carcasses. During each survey, after removing scavengers, the carcass was brought to the surface and wet mass (± 100 g) determined, returned to the bottom, and re-tethered to the rope transect. By the fifth day, carcasses had begun to disintegrate and further weights were not possible.

The complete riparian zone between the estuary and the headwater lake was surveyed for carcasses during the spawning period twice in 1992, five times in 1993, and twice in 1994 yielding a cumulative yearly total transfer at the completion of the run of 1150, 3611, and 1596 carcasses, respectively; for a 3 kg Chum Salmon, bears consumed an average of 1.6 kg/carcass and abandoned 1.4 kg (full details in Reimchen 2000). The majority of salmon carcasses were distributed within a 50 m riparian band adjacent to the dominant spawning reaches in the stream and with highest densities occurring within 10 m of the stream.

Carcass consumption by scavengers other than bears was determined with two methods. First, I tagged and weighed 152 fresh *in situ* complete salmon carcasses (1992, $n = 89$; 1993, $n = 63$) abandoned by bears in the riparian zone and on successive days monitored any foraging activity on the carcasses. Following a foraging bout by a flock of birds, I re-examined the carcass and noted the type of tissues extracted. All carcasses were re-weighed every two days. Loss of mass from tissue dehydration was minimal due to the shade, moist substrate, and high humidity. Secondly, I used daily metabolic requirements combined with total days of presence for the common avian scavengers (e.g., Birtfriesen *et al.* 1989; Christie and Reimchen 2006). Blow flies (predominantly Calliphoridae) deposited eggs on carcasses within the first two days following transfer to the riparian zone and typically after three to five days, larvae dominated the carcasses. I estimated numbers of larvae per carcass using three separate methods: assume a density of 8 larvae per gram of tissue based on experimental forensic studies of Calliphorid larvae consuming liver (Goodbrod and Goff 1990),

empirically-derived regression (number of larvae = $268 + 3.0$ times carcass mass) based on dipteran larval production on Chum Salmon carcasses from mainland British Columbia (Hocking and Reimchen 2002), and empirical estimates of 22.4 larvae per g Sockeye Salmon (*Oncorhynchus nerka*) carcasses in Washington (Meehan *et al.* 2005). To determine density on the forest floor, I counted all larvae at seven plots (20 cm \times 20 cm) positioned at 0 m, 1 m, 2 m, and 3 m from the bony remnants one day after no further larvae were visible on the remnants.

To assess soil invertebrates, I took paired 175 cc soil plugs, the first from beneath the bony remnants, and a second 0.5 m distant from the first but on a similar substrate. The sites for the plugs were about 5 m from the stream bank and from 17 different sites extending over 100 m along the stream channel in the reaches of high spawning densities. Soil plugs were dried in separate Berlese funnels and all extracted invertebrates counted and identified to Order or Family.

In October 2000, a vegetation sampling grid was established in this watershed at 35 riparian sites between the estuary and the headwater lake, including 11 transects perpendicular from the stream into the forest across a previously documented gradient of high to low salmon carcass densities (Reimchen 2000). Within a 5 m radius of each targetted Sitka Spruce, the primary focus for the grid (Reimchen and Fox 2013), I sampled up to six plant species, the number dependent on their occurrence at each site: Lanky Moss (*Rhytidiadelphus loreus* (Hedw.) Warnst.), Deer Fern (*Blechnum spicant* (L.) Roth), Red Huckleberry (*Vaccinium parvifolium* Smith), False Azalea (*Menziesia ferruginea* J. E. Smith), Salal (*Gaultheria shallon* Pursh), and Western Hemlock seedlings, the latter from intact nurse logs which were typically large fallen Sitka Spruce. For each of the sites, I measured distance (m) from the stream edge into the forest (DistForest). There was a gentle slope ($\sim 5^\circ$) across the riparian zone. For each species and from each of three separate plants, I collected up to six leaves or needles that were later oven-dried at 60°C for 2–3 weeks. One mg of tissue was powdered, packaged, and processed for nitrogen isotope signatures and total nitrogen at the Stable Isotope Facility, University of Saskatchewan, using a Europa Scientific ANCA NT gas/solid/liquid preparation module coupled to a Europa Scientific Tracer 20-20 mass spectrometer (PDZ Europa, Cheshire, England). Four species were common throughout the sampling grid and I restrict analyses to these ($n = 314$). Natural abundance of ^{15}N is expressed as the deviation from atmospheric N_2 (‰) and calculated as $\delta^{15}\text{N} = (R_{\text{sample}}/R_{\text{standard}} - 1)$ where R is the ratio of $^{15}\text{N}/^{14}\text{N}$ stable isotopes. Measurement precision is $\pm 0.35\text{‰}$.

Relative contribution of marine-derived nitrogen (%MDN) for each of the four plant species was calculated using:

$$\% \text{MDN}_i = (\text{OBS}_i - \text{TEM}_i) / (\text{MEM} - \text{TEM}_i)$$

where OBS_i is the $\delta^{15}N$ value for species i , TEM_i is the terrestrial end member for species i , and MEM is the value ($\delta^{15}N = 11.1\text{‰}$) for Chum Salmon, the marine end member (Johnson and Schindler 2009). For each species, I used a TEM for non-carass sites that are sites greater than 60 m from the stream where no carcasses were observed, as well as sites greater than 1200 m upstream beyond the upper distribution of spawning gravels and where no carcasses were observed (#20, 17, 14, 8, 11, 32, 30, 29, 28; Figure 1).

Statistics

All analyses were run using SPSS v.24 (IBM, USA). For the 17 pairs of adjacent soil plugs, numbers of individuals (ln transformed) for each taxon were compared with paired t -tests while diversity was estimated using Shannon Diversity (H) and Equitability (E) indices. Foliar $\delta^{15}N$ values for each of the four riparian species were normally distributed while %N values violated assumptions of normality due to the strong positive skew of the data (Shapiro-Wilk, $P > 0.05$). Log transformations did not normalize the data so I used Box-Cox rank transformations. To visualize the spatial trends in the data, I initially plotted $\delta^{15}N$ for each species on a grid of the riparian microsites for distance upstream from the estuary and for distance into the forest in relation to presence or absence of salmon carcasses at the microsite. Secondly, I saved the $\delta^{15}N$ residuals for each species and plotted the combined data on the grid. In each species, $\delta^{15}N$ and %N were positively correlated with each other. To identify whether the presence/absence of a carcass was associated with these nitrogen variables, I ran a multivariate general linear model (GLM) using $\delta^{15}N$ and %N as dependents, Carcass (absence/presence) as a categorical independent variable, and DistForest as covariate. I then tested the main effect of Carcass on $\delta^{15}N$ and %N for each species.

Results

Basic food web

A simplified energy flow diagram of salmon at Bag Harbour is shown in Figure 2. Of the 6300 pre-spawned salmon returning from the open ocean in 1993, predation in the estuary, primarily by bears and pinnipeds, resulted in a 4% reduction of the total salmon biomass. The majority of salmon (96%) migrated upstream for spawning and approximately 20% of the post-reproductive carcasses were swept downstream into the estuary. These carcasses were scavenged by avian taxa and subtidal invertebrates. In the stream channel, bears captured or scavenged about 65% of the salmon, most of which ($n = 3700$) were transferred to the riparian zone, where bears consumed about one-half of each carcass. Gulls and crows scavenged about 7% of total carcass biomass on stream gravel bars and 12% of the carcass biomass in the riparian zone. Most of the soft tissues of riparian carcasses abandoned by bears were consumed by calliphorid larvae. In 1992, there were approximately half the carcasses compared with 1993. Taxonomic

diversity and total numbers of individual taxa seen in the estuary and watershed are summarized in Table 1. Most species were uncommon in the watershed prior to the salmon migration.

Mammals

Pinnipeds occurred in the estuary throughout the salmon spawning period, usually in low numbers during both years. Foraging on salmon was observed both during daylight and darkness, the latter facilitated by extensive bioluminescence produced during movement of the salmon. In autumn 1992, I recorded 42 daylight pursuits by Harbour Seals (*Phoca vitulina*) of which five were successful (12%). I could not determine success of the nocturnal pursuits. Handling and ingestion occurred at the surface and typically involved secondary scavenging by gulls (primarily Herring [*Larus argentatus*] and Glaucous-winged [*L. glaucescens*]) on the floating tissue remnants. Based on these observations, the total number of 'seal days' as well as the average daily salmon consumption of Harbour Seals (1.9 kg/day) in an estuary in southern British Columbia (P. Olesiuk, personal communication, December 1994). I estimated total capture/spawning run of approximately 80 salmon (1992: 266 kg; 1993: 239 kg). Up to four Steller Sea Lion (*Eumetopias jubatus*) also occurred in the estuary over the spawning period during both years, primarily during twilight and darkness. I could not reliably determine their foraging activities but combining the total 'sea lion days' at Bag Harbour and the daily salmon consumption of sea lions on Vancouver Island (G. Ellis, personal communication, December 1994). I estimated salmon consumption by sea lions in 1992 and 1993 at 80 and 10 salmon respectively (1992: 240 kg; 1993: 30 kg).

From four to eight Black Bears occurred in the watershed throughout the salmon spawning period. Summarizing from Reimchen (1994, 2000), a total of 4790 salmon were captured in 1993 of which 1030 were consumed in the stream channel while 3700 (10 970 kg) were transferred into the riparian zone for consumption (the others were in the estuary). These carcasses were most prevalent in riparian zones adjacent to high stream spawning densities. Most (80%) carcasses were dropped within 10 m of the stream with numbers declining at greater distances into the forest. Occasional carcass remnants could be found on bear trails up to 80 m from the stream. Mass of individual carcass remnants abandoned by bears averaged 1.3 kg ($n = 689$) and ranged from 2% to 98% (average $\pm 44\%$) of original carcass mass estimated from jaw length (Reimchen 2000). Percentage of each carcass abandoned by the bears was higher ($\sim 75\%$) following new migration of spawners into the stream (during rainfall and increased stream flow) and was lower ($\sim 35\%$) when salmon densities in the stream were low (following multiple days without rainfall). Based on the overall distribution and abundance of bear-transferred carcasses throughout the watershed, general density of abandoned tissues

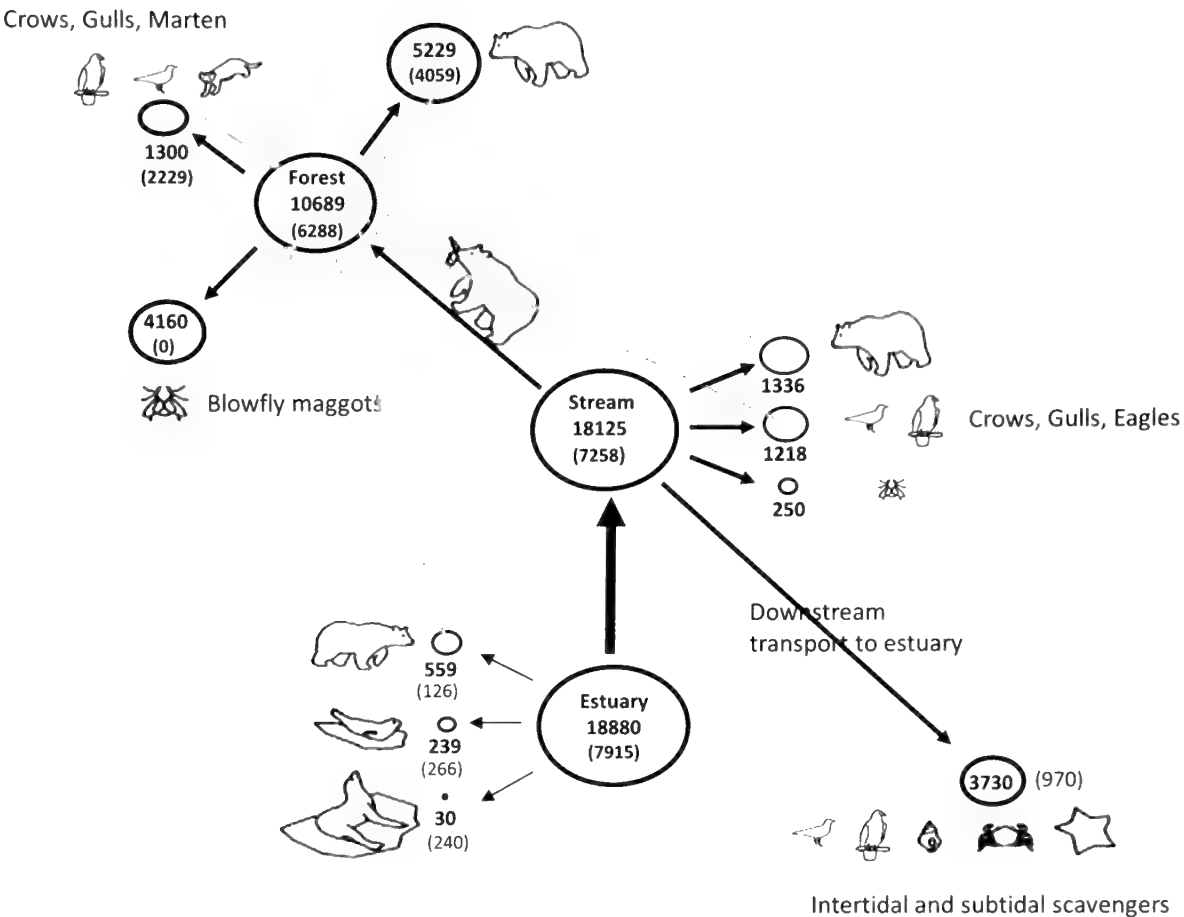


FIGURE 2. Summarized Chum Salmon (*Oncorhynchus keta*) nutrient flow at Bag Harbour, British Columbia for 1993 and 1992 (in brackets). All values shown in kg. Area of circle proportional to original biomass entering estuary. Dashed lines show dominant sources of nitrogen input to soil. See Table 1 for a complete list of all major taxa examined.

was 2730 kg/ha within a 10 m band adjacent to the stream and 171 kg/ha further into the forest (10–50 m). Small mammals were also resident in the watershed. Two American Marten (*Martes americana*) were commonly observed on the stream banks feeding on fresh carcass tissues abandoned by bears. I did not see any use of the much more abundant senescent carcasses by this scavenger. Based on direct observation, I estimated total salmon consumption by marten of ~20 kg in 1993. During a mid-November visit to the stream two weeks after the spawning run, I found 14 freshly killed gulls cached under trees adjacent to the stream channel where marten had been previously observed dragging fresh salmon remnants and I infer that these caches were made by the marten. On multiple occasions, gulls were seen resting on stream banks following extended bouts of salmon carcass consumption and I suspect this made them highly susceptible to capture by marten. As I only searched about a quarter of the root cavities in the spawning reaches, the 14 carcasses are probably a substantial underestimate of the total in the watershed. Several resident River Otter (*Lontra canadensis*) foraged for Coho Salmon in the tributary streams to the headwater.

Birds
Twenty-seven species of birds were recorded in the watershed during the study period (Table 1). Most were uncommon prior to and early in the spawning migration but increased over the duration of the spawning run. Scavenging occurred in nine species including multi-species flocks of gulls (primarily Herring and Glaucous-winged) reaching a maximum ($n = 375$) in mid-October and then declining towards the end of the spawning run. Near dawn and dusk, gulls consumed salmon eggs drifting from the stream into the estuary but also scavenged carcasses in the intertidal zone. During daylight, most gulls moved upstream from the estuary where they foraged on dislodged salmon eggs, senescent carcasses in the stream channel, and bear-abandoned carcasses on the gravel bars and stream banks. Based on the daily loss of carcass mass in addition to number of ‘gull days’, I estimate a total consumption of 900 kg of salmon tissues. Using daily metabolic requirements and cumulative ‘gull days’ yields an independent but similar estimate of 1160 kg of tissue. Northwestern Crows (~200) were prevalent on the estuary during the first two weeks of the spawning run but shifted upstream to riparian habitats in the

TABLE 1. Major taxa examined at Bag Harbour watershed, Haida Gwaii, British Columbia, during Chum Salmon (*Oncorhynchus keta*) migration. Counts of individual animals show daily maxima and averages for 1993 (most detailed) and 1992 (brackets). Chum Salmon spawning numbers are 6300 (1993) and 2700 (1992). Riparian vegetation samples were collected in October 2000 (for δ¹⁵N and ‰N) and show sample sizes for each species. nc = not counted.

Species showing direct consumption of salmon	Daily maximum	Daily average
PRIMARY VERTEBRATES IN THE WATERSHED		
Black Bear <i>Ursus americanus</i>	8 (4)	1.7 (0.9)
Steller's Sea Lion <i>Eumetopias jubatus</i>	1 (4)	
Harbour Seal <i>Phoca vitulina</i>	19 (8)	2.8 (3.3)
Marten <i>Martes Americana</i>	2	
River Otter <i>Lutra Canadensis</i>	1	
Bald Eagle <i>Haliaeetus leucocephalus</i>	4 (4)	1.5 (1.3)
Gulls* <i>Larus</i> spp.	375 (300)	121.6 (64.9)
Northwestern Crow <i>Corvus caurinus</i>	200 (300)	49.2 (102.5)
Common Raven <i>C. corax</i>	1 (4)	0.2 (0.2)
American Dipper <i>Cinclus mexicanus</i>	nc	nc
Winter Wren <i>Troglodytes troglodytes</i>	nc	nc
Varied Thrush <i>Ixoreus naevius</i>	nc	nc
TERRESTRIAL INVERTEBRATES†	nc	nc
MARINE INVERTEBRATES‡	nc	nc
SECONDARY VERTEBRATES IN THE WATERSHED		
Bat <i>Myotis</i> spp.	nc	nc
Common Loon <i>Gavia immer</i>	3 (5)	1.5 (7.5)
Pacific Loon <i>G. pacifica</i>	30 (65)	1.4 (10.5)
Horned Grebe <i>Podiceps auritus</i>	3 (3)	0.4 (0.5)
Red-necked Grebe <i>P. grisegena</i>	4 (5)	1.1 (1.8)
Western Grebe <i>Aechmophorus occidentalis</i>	8 (1)	2.0 (0.8)
Doubled-crested Cormorant <i>Phalacrocorax auritus</i>	1 (0)	0.0 (0.0)
Mallard <i>Anas platyrhynchos</i>	45 (4)	2.0 (0.3)
Green-winged Teal <i>A. crecca</i>	0 (23)	0.0 (2.5)
Scaup <i>Aythya</i> spp.	1 (10)	1.0 (2.2)
Common Goldeneye <i>Bucephala clangula</i>	0 (3)	0.0 (0.2)
Bufflehead <i>B. albeola</i>	4 (14)	1.4 (3.5)
Harlequin <i>Histrionicus histrionicus</i>	13 (10)	4.6 (4.7)
White-winged Scoter <i>Melanitta deglandi</i>	20 (68)	11.6 (44.0)
Surf Scoter <i>M. perspicillata</i>	16 (0)	0.7 (0.0)
Common Merganser <i>Mergus merganser</i>	0 (15)	0.0 (3.0)
Red-breasted Merganser <i>M. serrator</i>	6 (0)	0.4 (0.0)
Hooded Merganser <i>Lophodytes cucullatus</i>	5 (14)	0.6 (3.8)
Common Murre <i>Uria aalge</i>	0 (3)	0.0 (0.5)
Belted Kingfisher <i>Ceryle alcyon</i>	1 (1)	0.3 (0.6)
Great Blue Heron <i>Ardea herodias</i>	1 (0)	0.1 (0.0)
VEGETATION		
Lanky Moss <i>Rhytidiadelphus loreus</i>	88	
Red Huckleberry <i>Vaccinium parvifolium</i>	41	
Salal <i>Gaultheria shallon</i>	88	
Western Hemlock <i>Thuja heterophylla</i>	97	

*Primarily Glaucous-winged Gull (*Larus glaucescens*) and Herring Gull (*L. argentatus*).

†Terrestrial invertebrate data obtained in October 1993 (24 taxa; Figure 3).

‡Gastropoda, Crustacea, Echinodermata.

second half of the run (30 September to 20 October). They usually occurred in small flocks (10–30 individuals) in the immediate vicinity of bears that were feeding on freshly-captured salmon in the stream or the riparian zone and would quickly occupy the remnants when the bears abandoned the carcass. I did not observe crows foraging on senescent carcasses or on fly larvae that were prevalent in the riparian zone. Combining daily estimates of crow abundance (2800 ‘crow days’) and

their general foraging activity throughout the spawning run yields an estimated total consumption of 270 kg. Two weeks after the end of the spawning run, no crows were observed in the estuary, stream, or riparian zone. Among the birds foraging in the estuary, 21 species occurred that were either minor salmon consumers or were not directly associated with carcasses. Bald Eagle (*Haliaeetus leucocephalus*; maximum four) occurred daily throughout the spawning period and based on

direct observation of their foraging activity, I estimate a total consumption of ~ 20 kg of fresh salmon tissues abandoned by bears. However, based on daily salmon consumption rates of captive Bald Eagles at 5 °C (Stalmaster and Gessaman 1982), the four Bald Eagles at Bag Harbour would consume 60 kg over the spawning period. Common Ravens were intermittently present (maximum four) and foraged on fresh salmon carcass remnants abandoned by bears and I estimate total consumption at 5 kg. American Dipper (*Cinclus mexicanus*; maximum three) foraged on salmon eggs in the stream throughout the study period (no biomass estimated). Eighteen bird species, not seen in direct association with salmon carcasses, appeared in the estuary following the onset of the spawning run and were present throughout the duration of the run. Foraging by each species was common every day. During SCUBA transects, I observed large schools of clupeid-like fish in areas where diving birds (primarily Pacific Loon [*Gavia pacifica*]) were present and I infer these were the target of the divers. White-winged Scoters (*Melanitta fusca*) were prevalent near the stream mouth and consumed drifting salmon eggs, carcass remnants, and small crustaceans associated with the submerged salmon carcasses. Mallards (*Anas platyrhynchos*) became very common on the estuary after the completion of spawning run but I was not able to identify prey items of these dabblers.

Terrestrial invertebrates

Invertebrate scavengers, primarily calliphorid blowfly larvae, were major consumers of salmon carcasses but their abundance was highly variable among years. In autumn 1992, when 2000 salmon were transferred by bears to the riparian zone, I did not observe any carcasses with blowfly eggs or larvae. In contrast, in autumn 1993, when 3700 carcasses were transported by bears to similar regions of the riparian areas as in 1992, 95% of carcasses had blowfly egg masses and these hatched within several days resulting in high densities of larvae that fully enveloped the carcass remnants. Daily surveys to these carcasses showed consumption of all soft tissues by the larvae in five to seven days. Total counts of larvae per carcass, assuming a 1.3 kg average carcass mass of abandoned tissues, are estimated at 4200 based on estimates derived from Hocking and Reimchen (2002), 10 400 based on the eight larvae/gram of tissue from Goodbrod and Goff (1990), and 29 000 based on empirical counts on Sockeye Salmon by Meehan *et al.* (2005). I will assume the conservative estimate. Larvae dispersed radially from the bony remnants and direct counts of dispersing larvae ranged from ~7000/m² within a half meter radius of the remnants to 200/m² at 3 m distance from any carcass remnants. Pre-pupal larvae burrowed into the moss-substrate, under and within woody debris, and were observed under the bark several metres up the vertical trunks of trees. Based on 95% of the carcasses with larvae, I estimate there would be 14.7 million larvae

produced during the 1993 spawning run. As 80% of the carcasses were within 10 m of the stream bank, average densities of dispersing larvae on the substrate would be 738/m² while further into the riparian zone (10–50 m) this would be reduced to 31 larvae/m² along the 800 m riparian band on each side of the spawning gravels. I found minimal evidence for mortality of the larvae either at the carcass site or during their subsequent dispersal on the forest floor. Despite monitoring hundreds of carcasses, the pungent odour and high temperatures of the dense larval masses appeared to exclude most other scavengers. Among the multiple bear scats observed, a single scat had large volumes of digested larvae indicating occasional consumption of these larvae-dominated carcasses or of dispersing larvae. Some larvae dispersed over the stream bank and were swept downstream.

Paired soil plugs ('below' bony remnants versus 'adjacent' to bony remnants) extracted from each of 17 separate carcass sites yielded 24 invertebrate taxa of which mites (Acari), springtails (Collembola), and dipteran larvae were the most abundant. Overall Shannon diversity (H) and Equitability indices were similar for 'below' and 'adjacent' microsites (H = 1.15 and 1.7, E = 0.36 and 0.36, respectively). While twenty of these taxa showed no statistical difference between the two microsites (paired *t*-test, *P* > 0.1 in all cases), four groups (mites, springtails, pseudoscorpions, and spiders) were more prevalent in the 'adjacent' microsite (*P* < 0.05 in each taxa) and two taxa (dipteran larvae and staphylinid beetles) were more common 'beneath' the bony remnants (*P* < 0.05 and *P* < 0.001, respectively; Figure 3).

Marine invertebrates

SCUBA surveys of 40 tethered subtidal carcasses yielded 10 species of macro-invertebrate scavengers. In the shallow transect (5 m), the dominant scavenger on the carcasses was Dire Welk (*Lirabuccinum dirum*; average = 7, range 0–250) and less frequently hermit crabs (*Pagurus* spp. average = 2.5, range 0–10), beach crab (*Hemigrapsus* spp. average = 0.4, range 0–10), Red-rock Crab (*Cancer productus* average = 0.9, range 0–4), broken-back shrimp (*Heptacarpus* spp. average = 0.1, range 0–5), and starfish (*Evasterias* spp. average = 0.1, range 0–1). The middle depth transect (10 m) had Dire Welk (average = 20, range 0–125), hermit crabs (average = 1.2, range 0–4), and broken-back shrimp (average = 2.7, range 0–15) while the deep transect (15 m) had Red-rock Crab (average = 1.4, range 0–6), starfish (*Pisaster* spp. average = 0.1, range 0–2), bat star (*Asterina* sp. average = 1.1, range 0–9), Sunstar (*Pycnopodia helianthoides* average = 0.1, range 0–1) and Leather Star (*Dermasterias imbricata* average = 0.1, range 0–1). Based on the daily mass measurements of each carcass, there was an average loss of 200 g/day/carcass. Tissues became progressively softer and after five to seven days of submersion, attempted handling of these carcasses produced a cloudy fine suspension of tissues into the water column. This disso-

lution was more rapid in carcasses from the shallow transects where *Lirabuccinum* snails dominated the carcasses. Secondary interactions with *Lirabuccinum* could be occurring after the spawning run as there was high abundance of recent crab-predated *Lirabuccinum* that had previously dominated the carcasses.

Riparian nitrogen input

Overall contribution of salmon-derived nitrogen to the riparian zone was estimated for the 1993 field season. Nitrogen comprises about 3.3% of total Chum Salmon mass (Gende *et al.* 2007) and when salmon are consumed by bears, most nitrogen is excreted as urine (96%) or faeces (3%; Hilderbrand *et al.* 1999). Therefore, of the 10690 kg uploaded by bears in 1993 along the 800 m of stream, 5230 kg was consumed, and 171.6 kg of nitrogen would be deposited on the forest floor. Of the 5460 kg of tissues abandoned by the bears in the riparian zone, most of this nitrogen (180 kg) would remain in the riparian zone from calliphorid larvae which pupated in the soil, scavenging

by flocks of crows and gulls whose guano was scattered throughout the riparian zone, and by decomposition and direct leaching of the carcasses into the substrate. In total, 352 kg of salmon-derived nitrogen would be added to the riparian zone during the eight-week salmon spawning period. Eighty percent of the carcasses were within a 10 m band adjacent to the stream channel throughout the 800 m of the spawning activity. This zone contained most of the bear activity, calliphorid larval density, and avian scavenger activity. Nitrogen concentration would average 17.6 g N/m² in this band and 1.1 g N/m² in the 10 m-50 m zone band further into the forest. These could be conservative estimates as they do not include any contribution of the 1600 kg of salmon consumed directly in the stream channel by bears and avian scavengers. Both bears and crows typically moved into the riparian zone between foraging bouts and would have further supplemented excretory nitrogen to the soils. This would add an additional 88 kg if all excretion occurred in the riparian zone between foraging bouts. Gulls foraging in the

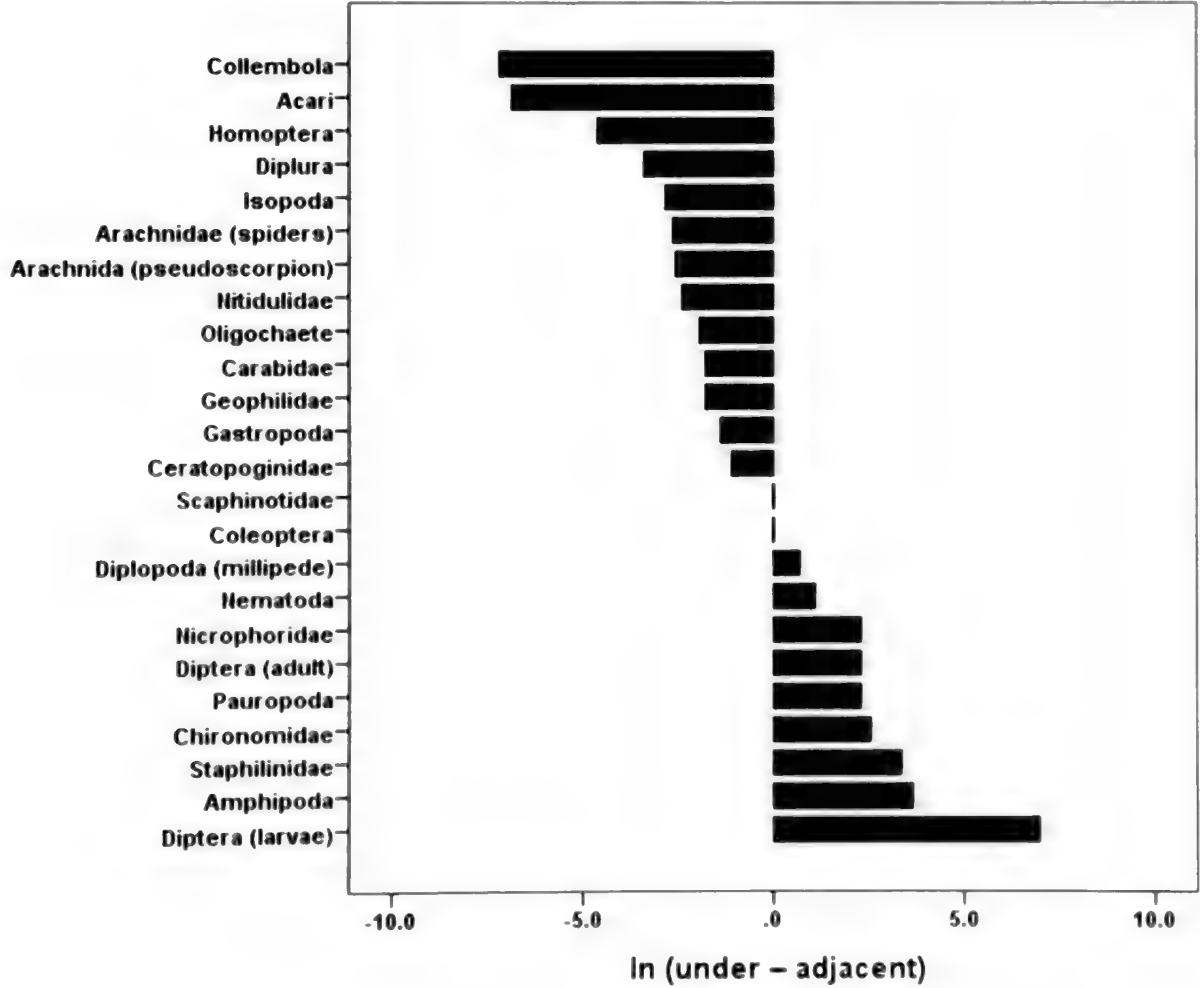


FIGURE 3. Differences in invertebrate diversity in paired soil plugs under and adjacent to Chum Salmon (*Oncorhynchus keta*) carcasses. All sites grouped. Data from October 2000. Bars show ln (number of individuals under carcass minus number of individuals adjacent to carcass). Values > zero indicate greater abundance under carcass.

stream channel could be observed resting on the stream banks and could supplement riparian nitrogen, but I will assume that the majority of their guano production took place in the stream channel, the estuary, or the headwater lake where gulls spent nights. Therefore, an upper range of nitrogen deposition to the 10 m riparian band along the 800 m of stream would be 405 kg or 20.9 g N/m².

Nitrogen signatures in riparian plants

Foliar $\delta^{15}\text{N}$ values were highly variable within each species (Lanky Moss, $n = 88$, $\bar{x} = -0.89\text{‰}$, range -10.4 to 9.9 ; Huckleberry, $n = 41$, $\bar{x} = 0.45\text{‰}$, range -8.2 to 6.5 ; Salal, $n = 88$, $\bar{x} = 1.07\text{‰}$, range -9.6 to 9.8 ; Western Hemlock, $n = 97$, $\bar{x} = -0.81\text{‰}$, range -8.3 to 7.2) with significant differences among the species ($F_{3,310} = 5.4$, $P < 0.001$). This variation in isotopic values showed spatial structure across the riparian zone (Figure 4) with ^{15}N depleted values in each species occurring at sites close to the estuary (< 200 m), at sites greater than 1000 m upstream and also those at increased distances (> 50 m) into the forests. Correspondingly, ^{15}N was more enriched from 300 to 800 m upstream, concordant with the general stream distribution of spawning gravels but also with site-specific carcass presence or absence. Among the habitat variables, Carcass was a more significant predictor of $\delta^{15}\text{N}$ than

DistForest in three of the four species (Lanky Moss: Carcass $F_{1,85} = 7.4$, $P < 0.005$, Distforest $F_{1,85} = 0.45$, $P = 0.5$; Huckleberry: Carcass $F_{1,38} = 1.53$, $P = 0.22$, Distforest $F_{1,38} = 3.64$, $P = 0.06$; Salal: Carcass $F_{1,85} = 7.89$, $P < 0.005$, Distforest $F_{1,85} = 0.47$, $P = 0.5$; Western Hemlock: Carcass $F_{1,94} = 21.83$, $P < 0.001$, Distforest $F_{1,94} = 5.10$, $P < 0.03$). I equalized means among the four species and plotted residuals for the combined data and this much larger dataset (Figure 5) shows clear spatial structure and carcass associations in isotopic enrichment (ANOVA: Carcass $F_{1,311} = 24.2$, $P < 0.001$; Distforest $F_{1,311} = 6.2$, $P < 0.02$).

Total foliar nitrogen (%N) varied among species (Lanky Moss: $\bar{x} = 0.91\%$, range 0.5 to 1.8; Huckleberry: $\bar{x} = 1.61$, range 0.7 to 2.3; Salal: $\bar{x} = 1.02\%$, range 0.7 to 2.1; Western Hemlock: $\bar{x} = 1.11\%$, range 0.5 to 2.3; ANOVA: $F_{3,310} = 49.6$, $P < 0.001$). In each of the species, %N was positively correlated with $\delta^{15}\text{N}$ (Lanky Moss: $r = 0.39$, $P < 0.01$; Huckleberry: $r = 0.62$, $P < 0.01$; Salal: $r = 0.35$, $P < 0.01$; Western Hemlock: $r = 0.36$, $P < 0.01$). Scatterplots of $\delta^{15}\text{N}$ against %N separated for absence/presence of carcasses are shown in Figure 6. The paired slopes (B) did not differ statistically from each other ($P > 0.3$ for Huckleberry, Salal, and Western Hemlock although $P = 0.06$ for Lanky Moss). Multivariate GLM with $\delta^{15}\text{N}$

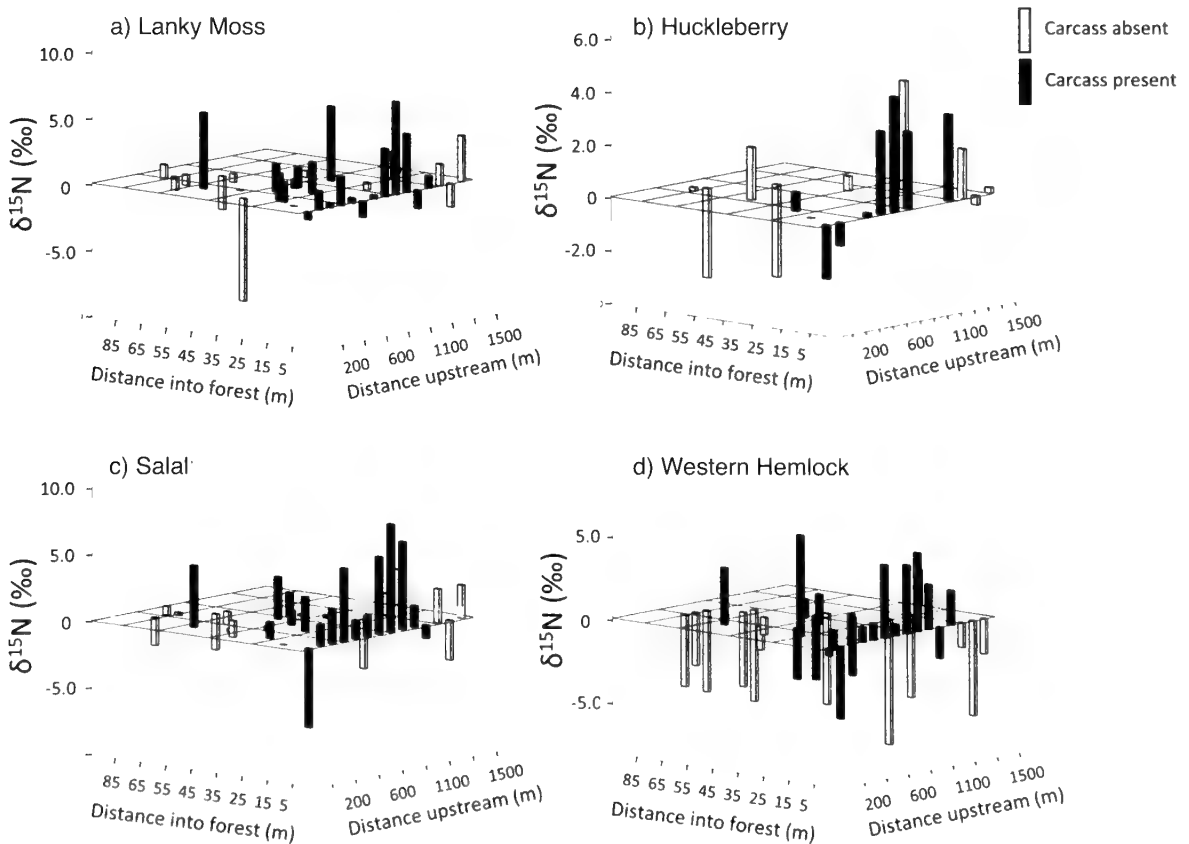


FIGURE 4. Average foliar nitrogen isotope values (‰) for riparian microsites separated by species. Note different scales for distance upstream and distance into the forest. False floor shows 0‰.

and %N as dependents, and Carcass and DistForest as predictors (Table 2) yielded significant models for both dependents although the explained variance (partial η^2) for the full models is low and usually between 10% and 30%. However, in each species except Huckleberry, %N and $\delta^{15}\text{N}$ were significantly higher in sites where carcasses were present. Additionally, %N decreased into the forest for Lanky Moss while $\delta^{15}\text{N}$ decreased into the forest for Western Hemlock.

%MDN in the foliar tissues varied with respect to species and microsite. It was lowest in Huckleberry (\bar{x} = 11.1%, range -67% to 60%), intermediate in Lanky Moss (\bar{x} = 13.6%, range -90% to 90%) and in Salal (\bar{x} = 16.6%, range -81% to 89%), and highest in Western Hemlock (\bar{x} = 24.9%, range -32% to 73%; $F_{3,227}$ = 2.5, P = 0.06). Negative %MDN values occurred when $\delta^{15}\text{N}$ values were lower than the control sites.

Discussion

Yearly migration of anadromous salmon (*Oncorhynchus* spp.) from the open ocean to coastal habitats of the North Pacific has great antiquity extending back at least 10 000 years in northern latitudes (Pielou 1991) and up to 10 million years south of the ice fronts (Alex-

androu *et al.* 2013). Despite the expanding recognition of the importance of this nutrient pulse to coastal ecosystems (Ben-David *et al.* 1998; Jauquet *et al.* 2003; reviews in Helfield and Naiman 2006; Johnson and Schindler 2009; Darimont *et al.* 2010), a characterization of a basic food web at the marine-terrestrial interface for a salmon spawning run has not been previously undertaken.

Estuarine congregations of gulls during salmon migration are well-known with their abundance generally proportional to total salmon spawning biomass (Field and Reynolds 2013). At two mainland estuaries, with salmon spawning runs of about 30 000 and 50 000 salmon, there were 2000 and 3500 gulls, respectively (6.5% and 7.2% of salmon numbers) and these consumed 20% of the total post-reproductive salmon biomass in each locality (Christie and Reimchen 2006). At Bag Harbour, 100 km off the west coast of the mainland, gulls were also one of the dominant scavengers. During the 1992 and 1993 spawning runs, gull numbers were 8% and 6% of salmon numbers, respectively, and consumed 30% and 10% of the spawning biomass, respectively, broadly similar to mainland watersheds. This concentrated foraging by gulls on a largely unrestricted nutrient source over multiple weeks is probably

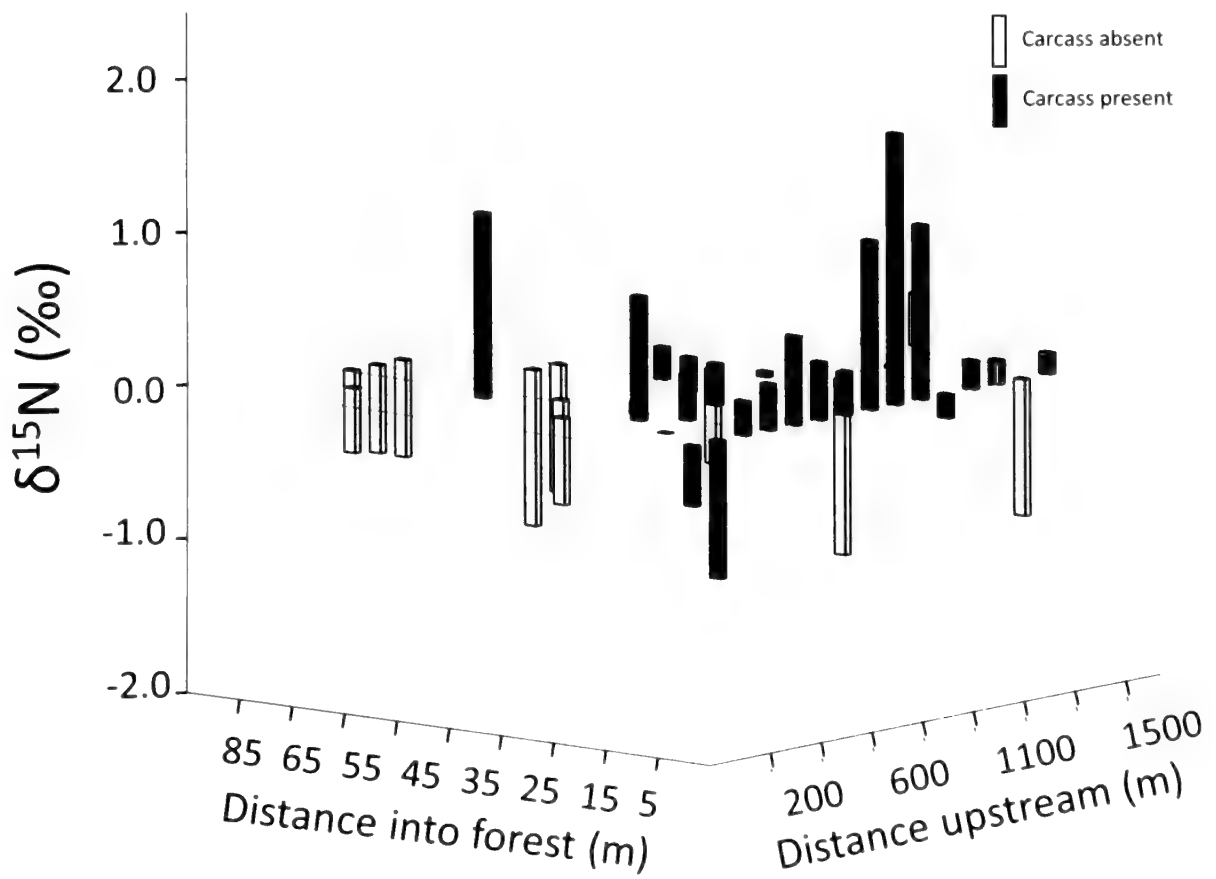


FIGURE 5. Average residual foliar nitrogen isotope values (‰) for riparian microsites with all species combined. Values represent residuals derived separately for each species. Note different scales for distance upstream and distance into the forest. False floor shows 0‰.

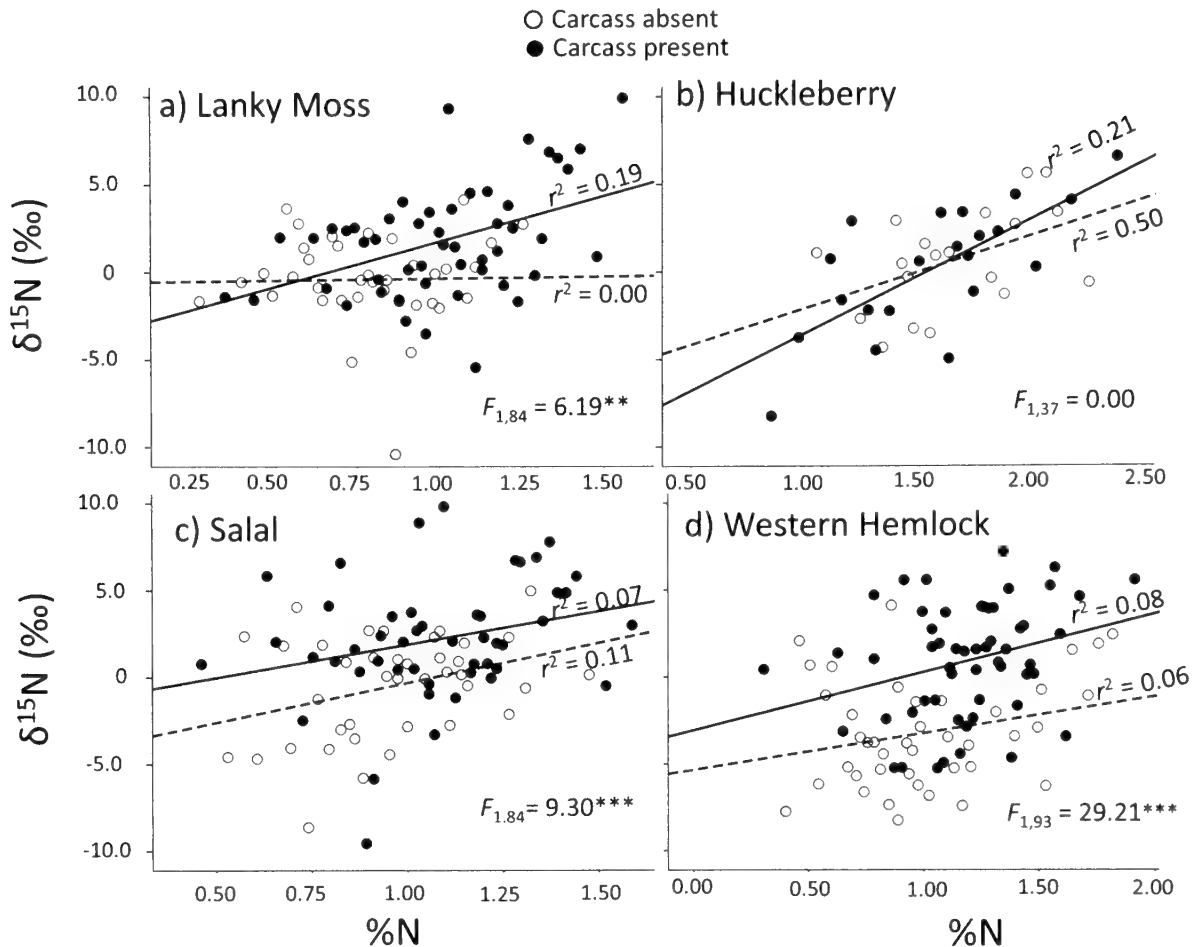


FIGURE 6. Associations between foliar $\delta^{15}\text{N}$ and percent nitrogen (%N) for riparian taxa. Plots show r^2 and F statistic for comparisons between the regression line marginal means for sites with Chum Salmon (*Oncorhynchus keta*) carcasses absent or present. The paired slopes did not differ statistically from each other ($P > 0.3$ in Huckleberry [*Vaccinium parvifolium*], Salal [*Gaultheria shallon*], and Western Hemlock [*Tsuga heterophylla*] and $P = 0.06$ in Lanky Moss [*Rhytidadelphus loreus*]). All %N data are normalized using Box-Cox transformation (see Methods). *** $P < 0.001$ ** $P < 0.01$.

of considerable importance. As in many marine birds, food constraints are common during their life history, particularly during winter (Lack 1966; Coulter 1975), so it is likely that the geographical distribution of salmon spawning runs in addition to the biomass of each run will influence gull life histories throughout the north Pacific. The serendipitous observation of multiple gull carcasses cached beneath trees by resident marten extends the trophic linkages of the gull aggregations.

The extent of salmon carcass consumption by estuarine subtidal scavengers has received limited attention. Large decapods such as the Dungeness Crab (*Cancer magister*) and Red-rock Crab are geographically widespread scavengers (Thorne *et al.* 2006). But while present in Bag Harbour estuary, Dungeness Crab were not observed on carcasses. Such absence might reflect the low tissue quality of senescent carcasses (Winder *et al.* 2005) or possibly that they were more active during darkness rather than daylight when I surveyed (e.g., McGaw 2005). At Bag Harbour, ~3700 kg of salmon biomass was washed into the estuary and the major sca-

vengers I observed in shallow depths were gastropods and species of hermit crab with prawns and echinoderms at greater depths. High densities of these scavengers on the carcasses may be an important trophic link in productivity and diversity in estuaries. Fujiwara and Highsmith (1997) identified a positive feedback loop in which the downstream accumulation of salmon carcasses in estuaries increased nitrates and phosphates that stimulated growth of the macrophyte *Ulva*. *Ulva*, in turn, was the major food of harpacticoid copepods, the latter comprising an important prey of juvenile salmon. As well, watershed size and salmon density were positively associated with growth responses in estuarine intertidal bivalves (Harding *et al.* 2015). Cak *et al.* (2008) also found estuarine increases in nutrients from salmon carcasses, but without effects on primary productivity. During my SCUBA surveys at Bag Harbour, full dissolution of the carcasses into the estuarine water column occurred after 5–7 days of submergence that would have increased organic carbon, nitrates, and phosphates. The partially restricted tidal entrance to

TABLE 2. Multivariate general linear model for foliar $\delta^{15}\text{N}$ and foliar ‰N using Chum Salmon (*Oncorhynchus keta*) Carcass (absence/presence) as a fixed factor and DistForest as covariate for riparian species in Bag Harbour, British Columbia. Source (Model, Carcass, Distforest) shows slope (±) of regression line. Model represents the corrected model. All significant results are shown in bold.

Species	Dependent	Source	<i>F</i> _{adj}	<i>P</i>	Partial η^2
Lanky Moss	$\delta^{15}\text{N}$	Model+	5.97 _{2.84}	0.004	0.12
		Carcass+	7.17 _{1.84}	0.009	0.08
		DistForest-	0.40 _{1.84}	0.530	0.01
	‰N	Model+	12.51 _{2.84}	0.000	0.23
		Carcass+	5.58 _{1.84}	0.020	0.06
		DistForest-	7.51 _{1.84}	0.008	0.08
Huckleberry	$\delta^{15}\text{N}$	Model+	1.86 _{2.37}	0.170	0.09
		Carcass-	1.69 _{1.37}	0.200	0.04
		DistForest-	3.52 _{1.37}	0.070	0.09
	‰N	Model+	0.88 _{2.37}	0.430	0.05
		Carcass-	1.45 _{1.37}	0.240	0.04
		DistForest-	1.13 _{1.37}	0.300	0.03
Salal	$\delta^{15}\text{N}$	Model+	6.98 _{2.87}	0.002	0.14
		Carcass+	10.69 _{1.87}	0.002	0.11
		DistForest-	0.08 _{1.87}	0.790	0.00
	‰N	Model+	4.67 _{2.87}	0.012	0.10
		Carcass+	8.76 _{1.87}	0.004	0.09
		DistForest+	3.72 _{1.87}	0.060	0.04
Western Hemlock	$\delta^{15}\text{N}$	Model+	22.83 _{2.93}	0.000	0.33
		Carcass+	20.72 _{1.93}	0.000	0.18
		DistForest-	5.38 _{1.93}	0.023	0.06
	‰N	Model+	5.95 _{2.93}	0.004	0.11
		Carcass+	11.71 _{1.93}	0.001	0.11
		DistForest+	3.882 _{1.93}	0.052	0.04

Bag Harbour (see Figure 1) would limit the daily mixing of tidal waters that would extend the duration of nutrients and benefits to productivity and may have contributed to the high densities of schooling fish and avian piscivores during, and after, the spawning run.

In stream channels, salmon nutrients make significant contributions to primary productivity (Cederholm *et al.* 1989; Thomas *et al.* 1999), to diversity and abundance of aquatic invertebrate scavengers (Nakajima and Ito 2003; Quamme and Slaney 2003; Wipfli *et al.* 2003), and to juvenile salmonid production (Bilby *et al.* 1996; Slaney *et al.* 2003; review in Stockner and Ashley 2003). This is in addition to their direct use by predators such as bears, wolves, marten, and birds (Ben-David *et al.* 1997; Cederholm *et al.* 1999; Hilderbrand *et al.* 1999; Klinka and Reimchen 2002, 2009; Darimont *et al.* 2003). In each year of my study, throughout much of the 800 m of the stream spawning areas, large flocks of gulls and crows were active throughout the day while bears occurred throughout daylight and darkness (Reimchen 1998). Aquatic invertebrate scavengers were not dominant in Bag Harbour stream channel during my study. Many of the senescent carcasses that accumulate in pools and are typically exploited by these scavengers had low residence time during my study as carcasses were usually swept downstream into the estuary by the high water flows. This

would limit the contribution to both primary and invertebrate scavenger productivity during high flow years.

Predator-mediated uploading of salmon carcasses to the riparian zone and their use by scavengers was first systematically documented in the Olympic Peninsula, western Washington, by Cederholm *et al.* (1989). My studies at Bag Harbour, Haida Gwaii, broadened the evidence for the major contribution of bears in such uploading (Reimchen 1992, 1994, 2000), while independent studies in coastal Alaska show a major role of Grizzly Bear (*Ursus arctos*) in the transfer of salmon nutrients to riparian zones (Hilderbrand *et al.* 1999, 2004; Gende *et al.* 2004). Although more limited in their effect, other predators such as Gray Wolf (*Canis lupus*), marten, and avian scavengers including gulls and eagles can be locally important in some watersheds (Ben-David *et al.* 1997; Darimont *et al.* 2003; Christie and Reimchen 2006). Flooding during heavy rainfall can also have an effect in low gradient watersheds (Ben-David *et al.* 1998; Bilby *et al.* 2003).

Despite the ecological importance of the contribution of salmon to riparian zones, the densities of riparian carcasses have not been previously quantified in studies of the marine-terrestrial interface. Data for Bag Harbour demonstrate an average occurrence of 2.3 carcasses per linear metre on each side of the stream, or approximately one carcass per 5 square metres in the 10 m wide

riparian band. While scavengers such as crows and marten exploited this resource, the principal consumers of the soft tissues were dipteran larvae. In 1993, 95% of the carcasses were fully enveloped in dipteran larvae resulting in consumption of most tissues. Published estimates of total dipteran larvae per carcass vary from 4000 to 29000 (Goodbrod and Goff 1990; Hocking and Reimchen 2002; Meehan *et al.* 2005). I used the most conservative of these values and this predicts the total abundance of 15 million larvae in the Bag Harbour riparian zone or approximately 740/m². Soil plugs extracted from multiple microsites yielded 24 invertebrate taxa, including predatory arthropods such as staphylinid and carabid beetles that would exploit both larvae and pupae (e.g., Allen and Hagley 1990; Hocking and Reimchen 2002). Recent studies on mainland watersheds indicate a rich assemblage of 60 invertebrate species including a diversity of Diptera, predatory beetles, and predatory wasps directly or indirectly associated with salmon carcasses (Hocking and Reimchen 2006; Hocking *et al.* 2009; Juen and Tragott 2007). Such diversity benefits vertebrate insectivores (Jauquet *et al.* 2003; Christie and Reimchen 2008; Christie *et al.* 2008).

Riparian densities of calliphorid larvae differed dramatically between sequential years. Larvae were not observed on any of the 800+ riparian carcasses observed in autumn 1992 yet these dominated the majority of carcasses in autumn 1993 (Figure 2). This large yearly difference was unexpected for an intact old growth forest because the major ecological players (salmon, bears, Diptera) were present each year of the study. While there could be cyclicity in calliphorid population trends, I suspect the yearly effects are due to temperature and insect flight activity. Average October daytime air temperatures for Bag Harbour (extracted from the closest Environment Canada meteorological station at Sandspit, British Columbia) were 5.6 °C in 1992 and 9.2 °C in 1993 while lowest daytime temperatures were 2.0 °C and 7.5 °C, respectively. Relative flight activity of large dipterans as well as larval development is greatly reduced below 10 °C (Chappell and Morgan 1987; Heaton *et al.* 2014) and could be the principal cause for the lack of egg production of the dipterans during the low 1992 temperatures. Such covariation between yearly autumn temperatures and trophic associations in the riparian zone suggests broader geographical trends among salmon watersheds from southern and northern latitudes or among salmon species that spawn at different times of the year. It also implies microspatial heterogeneity in trophic associations with sun exposure and temperature regime of individual carcasses. For example, salmon carcasses abandoned by bears in shaded areas of the riparian zone (i.e., shaded side of a tree trunk) would be less likely to receive visits from egg-laying dipterans and these carcasses would have extended use by vertebrate scavengers. Comparable trends in development rate have been observed in experimental forensic studies with

blowfly larvae on shaded and unshaded pig carcasses (Shean *et al.* 1993). Such heterogeneity might contribute to the large differences in isotopic values among microsites in the riparian zones in this study, a trend also seen in microgeographical differences in isotopic signatures of bryophytes of mainland salmon watersheds (Wilkinson *et al.* 2003) as well as soil nitrogen signatures in riparian zones of Alaskan salmon rivers (Holtgrieve *et al.* 2009).

Estimates of salmon-derived nitrogen subsidies to riparian soils from predator and scavenger activity in the northeast Pacific are highly variable within and among watersheds. Based on salmon consumption rates by Alaskan Brown Bears (= Grizzly Bears), nitrogen contributions to the riparian soils were estimated at 0.005 g N/m², of which 97% is added via urine (Hilderbrand *et al.* 1999). Gende *et al.* (2007), also investigating Alaskan Brown Bears, calculated contributions of 1.4 g N/m² to 10.5 g N/m² in a riparian band immediately adjacent to the salmon stream. Recent experimental evidence involving bear exclusion zones indicate substantive deficiencies in soil nitrogen processing compared with sites with bear activity (Holtgrieve *et al.* 2009). For the Bag Harbour watershed, I have incorporated carcass, bear and avian activity as well as invertebrate sources and estimate an average input of 18.8 g N/m² within a 10 m band of the stream and a 1.12 g N/m² at greater distances (10–50 m) along the riparian zone adjacent to the 800 m length of spawning gravels. If these groups were distributed uniformly over the entire riparian area (0–50 m band) rather than predominantly within the 10 m band where most of the carcasses, faeces, and scavenger activity were observed, then average nitrogen input would be 4.7 g N/m², which is about three to 30 times higher than those observed for Alaskan Brown Bears. Atmospheric nitrogen fixers such as Red Alder (*Alnus rubra* Bongard) are also sources of the soil nitrogen pool in coastal riparian zones with yearly fixation ranging from 3.5 g N/m² to 13.0 g N/m² (Binkley 1982). Alder is uncommon in the riparian zone at Bag Harbour watershed and as such, my estimates from the uploading of salmon nutrients by Black Bears over the eight weeks are equivalent to that of the yearly nitrogen fixation for a pure stand of Red Alder. Other limiting nutrients, such as phosphorus, that can constrain plant growth in coastal forests (Blevins *et al.* 2006), would also be supplemented with the salmon carcasses. Some of this riparian soil nitrogen could be lost due to groundwater movement and hyporheic flow into the stream and estuary (O'Keefe and Edwards 1993; Ben-David *et al.* 1997) although meta-analysis of attenuation rates indicates high nitrogen retention in undisturbed riparian zones, particularly in watersheds with low relief (Ranalli and Macalady 2010), which is the case for Bag Harbour.

The last three decades have seen a major expansion of stable isotope techniques in ecological studies (Fry 2006) including the identification of marine-derived nitrogen in foliar tissues of riparian habitats adjacent

to salmon rivers (e.g., Ben-David *et al.* 1998; Hilderbrand *et al.* 1999; Bilby *et al.* 2003; Reimchen *et al.* 2003; Nagasaka *et al.* 2006; Naiman *et al.* 2009). However, numerous processes can result in ^{15}N enrichment in foliar tissues including increased annual temperature, reduced rainfall, increased root depth, reduction in mycorrhizal fungi, and increased soil nitrogen availability (Craine *et al.* 2009, 2012, 2015), each of which can potentially produce false signals of marine-derived nitrogen sources in vegetation. Paired sampling across sharp ecological gradients in salmon carcass density (Mathewson *et al.* 2003; Wilkinson *et al.* 2005; Reimchen and Fox 2013), in bear activity zones (Hilderbrand *et al.* 1999) as well as experimental addition of salmon carcasses to virgin sites (Hocking and Reynolds 2012) provide improved confidence in interpreting nitrogen isotope signatures and sources. My study showed that higher isotopic ratios occurred in zones of high carcass density and bear foraging activity close to the spawning gravels and that ratios were reduced at greater distances into the forest where carcasses were absent and bear activity reduced. Although this is suggestive of a causal relationship, such a riparian isotopic gradient also occurs in Alaska streams without salmon and reflects denitrification (and subsequent enrichment) in the soils adjacent to streams (Bilby *et al.* 2003). This could be contributory to the gradient I observed but given that enrichment occurs at replicated carcass sites and depletion at adjacent non-carcass sites, the differences in ratios are consistent with the proximal effects of carcasses rather than effects of denitrification. Furthermore, the greatest reduction in $\delta^{15}\text{N}$ occurred near the upper reaches of the spawning gravels across a sharp gradient in carcass density yet within the same narrow riparian band adjacent to the stream. Comparable sharp isotopic differentiation in multiple riparian herbs and shrubs occurred on mainland watersheds immediately below and above waterfall barriers to salmon migration (Mathewson *et al.* 2003), as well as among bryophytes separated by several meters on and off bear trails (Wilkinson *et al.* 2005).

Among the four plant species I examined at Bag Harbour, isotopic values among microsites ranged from a minimum of -10.4‰ to a maximum of 9.9‰ . In an assessment of ^{15}N variability of multiple plant taxa from a diversity of geographical latitudes, temperatures, precipitation, and edaphic conditions, Craine *et al.* (2015) found that 95% of the isotopic data ranged between -7.8‰ and 8.7‰ . As such, even when factoring in the positive relationship between sample size and isotopic range (Craine *et al.* 2009), the Bag Harbour data equal or exceed the maximum range observed in the global survey. This high microsite variability cannot be due to taxonomic bias as it occurred in each taxa including a bryophyte, two ericads, and a gymnosperm. This variability is probably representative of the level of microspatial heterogeneity in edaphic conditions, including nitrogen availability that may differentiate salmon watersheds from non-salmon watersheds.

Estimates of the relative contribution of marine-derived nutrients (%MDN) depend on geography and taxonomy but tend to vary from 10% to 30%, with occasional higher values (Bilby *et al.* 1996, 2003; Hilderbrand *et al.* 1999; Helfield and Naiman 2001; Mathewson *et al.* 2003). I estimated that %MDN averaged 18% at Bag Harbour with maximum estimates for individual plants of 60% in Huckleberry to 89% in Lanky Moss and Salal. Such high estimates have been reported for individual growth rings in Sitka Spruce from this location (Reimchen and Fox 2013), as well as from shrubs in high salmon density watersheds on the British Columbia mainland (Mathewson *et al.* 2003). However, I suspect that true estimates at Bag Harbour could be even higher, due to two factors. Firstly, for a terrestrial end member for each species, I used ^{15}N values from plants collected above the upper distribution of spawning gravels as well as those distant into the forest beyond the outer distribution of salmon carcasses. Yet even in such ‘control’ sites, there was possible input of guano from flocks of crows or urine from bears moving through the sites. As such, the samples would be enriched relative to a ‘true’ control site resulting in lower %MDN estimates. Moving greater distances away from the stream to minimize such occasional nutrient influences increases the confounding impacts of the multiple abiotic and mycorrhizal associations known to influence nitrogen isotope ratios in plants (Craine *et al.* 2009). Secondly, artificially low estimates are indicated by the occasional negative %MDN where foliar ^{15}N values are less than the control. As these negative values occurred at sites with very high bear activity, I suspect that these soils were nitrogen saturated. Plants will discriminate against ^{15}N when nitrogen supply exceeds requirements and as a result, foliar tissues will be depleted in the heavy isotope (Nadelhoffer and Fry 1994). This implies that the extent of isotopic enrichment should scale positively with the relative loading of salmon-derived nutrients when the supply of nitrogen is less than that required by the plants but then scale negatively (increased fractionation) as the supply begins to exceed requirements (see Bilby *et al.* 2003; Hocking and Reimchen 2009; Hocking and Reynolds 2011). Most forests around the north Pacific are nitrogen-limited (Waring and Franklin 1979; Litke *et al.* 2014) but when large allochthonous nitrogen pulses occur, as in the bear-mediated uploading of salmon nutrients, surplus nitrogen is possible. Consequently, estimates of %MDN based on the absolute values of $\delta^{15}\text{N}$ in relation to a TEM, will greatly underestimate %MDN when nitrogen supplies to specific microsites exceed requirements. Such fractionation against ^{15}N should occur particularly for seedlings and small shrubs where surplus loading is possible. In large trees, nitrogen surplus would rarely occur. One would also predict that if the soil is nitrogen saturated, there would be elevated ‰N in the tissues. The elevated ‰N that I detected occurred in three of the four plant species collected in the high bear activity zones close to the estuary.

Does this input of salmon-derived nutrients increase riparian primary productivity? Such a positive effect could be expected given that most forests around the north Pacific are nitrogen limited (Waring and Franklin 1979). Enhanced growth rates in the riparian zone have been shown for Sitka Spruce in Alaska (Helfield and Naiman 2001) and at Bag Harbour, where there were significant positive growth responses in microsites where carcasses were prevalent and in years when spawning runs were elevated (Reimchen and Fox 2013). Foliar %N is also a proxy for primary production because a doubling of foliar nitrogen results in a 50% increase in chlorophyll content (Yoder and Pettigrew-Crosby 1995), which is itself directly correlated with primary productivity both for canopy and under-canopy habitats (Dawson *et al.* 2003). Craine *et al.* (2012) observed that foliar $\delta^{15}\text{N}$ and %N in many species are positively correlated with each other across broad geographical areas, independent of marine associations, and that both are elevated where soil nitrogen levels are high. In each plant species in my study, there was also a significant positive relationship between $\delta^{15}\text{N}$ and %N. Higher values for both proxies occurred in the highest carcass transfer zones suggesting a direct increase in primary productivity in the high bear activity sites.

My observations at Bag Harbour on estuarine, stream, and riparian movement of salmon biomass, bear transfer, scavenger diversity, and nitrogen uptake by riparian vegetation are taxonomically and trophically more detailed than previous studies and are probably representative for an intact watershed from current time periods. Yet numbers of returning salmon in 1993, when most detailed field data were obtained, were approximately one-half the yearly average (10 000) and one-sixth the maximum (35 000) number of salmon returning to this watershed between 1947 and 2000 (Marshall *et al.* 1978; Reimchen 1994). Further, these greater numbers in the recent past may seriously underestimate numbers from the late 1800s prior to the expansion of the commercial fishing industry (Gresh *et al.* 2000). Developing restoration targets for compromised habitats is facilitated with insight on the 'pre-disturbance' state but for much of the globe, ecological baselines have not been identified. This deficiency is confounded by expanding anthropogenic influences on all aquatic and terrestrial ecosystems that result in continuously shifting baselines that further limits the identification of pre-disturbance states using present day habitats (Arcese and Sinclair 1997). Even in well-studied taxa such as the great herds of African ungulates or the immense schools of marine clupeids, pre-historical densities are either unknown or at best interpolated (e.g., Finney *et al.* 2002).

Restoration of degraded stream and riparian habitats is an important component of reclamation in the Pacific Northwest (Lackey 2003). An overview of restoration practices for the western United States (Kauffman *et*

al. 1997; Slaney and Martin 1997) examined the importance of salmon to stream habitats but failed to address their role in riparian habitats, presumably because such information was still poorly known. However, during the last 20 years, multiple studies have identified the major contributions of salmon nutrients to riparian habitats and the resulting trophic cascades on species diversity and productivity. Yet, despite this accumulating evidence, a recent synthesis and development of policy guidelines for the restoration of stream and riparian habitats in the Columbia River basin (Rieman *et al.* 2015) again excludes assessment of carcasses in the riparian zone. The current study at Bag Harbour provides empirical data on carcass densities, their scavengers, and total nitrogen input that can inform ecological baselines and restoration targets.

Acknowledgements

I thank Colin French, Doug Burles, Bristol Foster, Peter Mylechrest, Todd Golumbia, Deanna Mathewson, Leigh-Anne Isaac, Hana Hermanuk, and Crystal Rausch for field assistance, multiple lab volunteers for stable isotope preparation of plant samples, Neville Winchester and Richard Ring for insect identification, Carolyn Bergstrom and Caroline Fox for statistical comments, Peter Olesiuk and Graham Ellis (Fisheries and Oceans Canada) for data on pinniped daily food consumption, and Sheila Douglas and Barbara Hawkins for discussion and comments on the manuscript. I acknowledge the Council of the Haida Nation for permission to undertake this research in their territories. This research was initially funded by Parks Canada, subsequently by the David Suzuki Foundation and an NSERC operating grant to the author (NRC 2354).

Literature Cited

- Alexandrou, M. A., B. A. Swartz, N. J. Matzke, and T. H. Oakley. 2013. Genome duplication and multiple evolutionary origins of complex migratory behavior in Salmonidae. *Molecular Phylogenetics and Evolution* 69: 514–523. <https://doi.org/10.1016/j.ympev.2013.07.026>
- Allen, W. R., and E. A. C. Hagley. 1990. Epigeal arthropods as predators of mature larvae and pupae of the apple maggot (Diptera: Tephritidae). *Environmental Entomology* 19: 309–312. <https://doi.org/10.1093/ee/19.2.309>
- Arcese, P., and A. R. E. Sinclair. 1997. The role of protected areas as ecological baselines. *Journal of Wildlife Management* 61: 587–602. <https://doi.org/10.2307/3802167>
- Banner, A., W. H. MacKenzie, J. Pojar, A. MacKinnon, S. C. Saunders, and H. Klassen. 2014. A field guide to ecosystem classification and identification for Haida Gwaii. B.C. Land Management Handbook 68. Province of British Columbia, Victoria, British Columbia, Canada. Accessed 14 March 2018. <http://www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh68.htm>.
- Ben-David, M., R. W. Flynn, and D. M. Schell. 1997. Annual and seasonal changes in diets of martens: evidence from stable isotope analysis. *Oecologia* 111: 280–291. <https://doi.org/10.1007/s004420050236>
- Ben-David, M., T. A. Hanley, and D. M. Schell. 1998. Fertilization of terrestrial vegetation by spawning Pacific salmon:

- the role of flooding and predator activity. *Oikos* 83: 47–55. <https://doi.org/10.2307/3546545>
- Bilby, R. E., E. W. Beach, B. R. Fransen, J. K. Walter, and P. A. Bisson.** 2003. Transfer of nutrients from spawning salmon to riparian vegetation in western Washington. *Transactions of the American Fisheries Society* 132: 733–745. <https://doi.org/10.1577/T02-089>
- Bilby, R. E., B. R. Fransen, and P. A. Bisson.** 1996. Incorporation of nitrogen and carbon from spawning coho salmon into the trophic system of small streams: evidence from stable isotopes. *Canadian Journal of Fisheries and Aquatic Sciences* 53: 164–173. <https://doi.org/10.1139/cjfas-53-1-164>
- Binkley, D.** 1982. Nitrogen-fixation and net primary production in a young Sitka alder stand. *Canadian Journal of Botany* 60: 281–284. <https://doi.org/10.1139/b82-036>
- Birtfriesen, V. L., W. A. Montevecchi, D. K. Cairns, and S. A. Macko.** 1989. Activity-specific metabolic rates of free-living northern gannets and other seabirds. *Ecology* 70: 357–367. <https://doi.org/10.2307/1937540>
- Blevins, L. L., C. E. Prescott, and A. Van Niejenhuis.** 2006. The roles of nitrogen and phosphorus in increasing productivity of western hemlock and western redcedar plantations on northern Vancouver Island. *Forest Ecology and Management* 234: 116–122. <https://doi.org/10.1016/j.foreco.2006.06.029>
- Cak, A. D., D. T. Chaloner, and G. A. Lamberti.** 2008. Effects of spawning salmon on dissolved nutrients and epilithon in coupled stream-estuary systems of southeastern Alaska. *Aquatic Sciences* 70: 169–178. <https://doi.org/10.1007/s00027-008-8090-5>
- Cederholm, C. J., D. B. Huston, D. L. Cole, and W. J. Scarlett.** 1989. Fate of coho salmon (*Oncorhynchus kisutch*) carcasses in spawning streams. *Canadian Journal of Fisheries and Aquatic Sciences* 46: 1347–1355. <https://doi.org/10.1139/f89-173>
- Cederholm, C. J., D. H. Johnson, R. E. Bilby, L. G. Dominguez, A. M. Garrett, W. H. Graeber, E. L. Greda, M. D. Kunze, B. G. Marcot, J. F. Palmisano, R. W. Plotnikoff, W. G. Percy, C. A. Simenstad, and P. C. Trotter.** 2000. Pacific salmon and wildlife-ecological contexts, relationships, and implications for management. Special edition technical report. Wildlife-habitat relationships in Oregon and Washington. Washington Department of Fish and Wildlife, Olympia, Washington, USA.
- Cederholm, C. J., M. D. Kunze, T. Murota, and A. Sibatani.** 1999. Pacific salmon carcasses: essential contributions of nutrients and energy for aquatic and terrestrial ecosystems. *Fisheries* 24: 6–15. [https://doi.org/10.1577/1548-8446\(1999\)024<0006:PSC>2.0.CO;2](https://doi.org/10.1577/1548-8446(1999)024<0006:PSC>2.0.CO;2)
- Chappell, M. A., and K. R. Morgan.** 1987. Temperature regulation, endothermy, resting metabolism, and flight energetics of tachinid flies (*Nowickia* sp.). *Physiological Zoology* 60: 550–559.
- Christie, K. S., M. D. Hocking, and T. E. Reimchen.** 2008. Tracing salmon-derived nutrients in riparian foodwebs: isotopic evidence in a ground-foraging passerine. *Canadian Journal of Zoology* 86: 1317–1323. <https://doi.org/10.1139/Z08-110>
- Christie, K. S., and T. E. Reimchen.** 2006. Post-reproductive Pacific salmon as a major nutrient source for large aggregations of gulls. *Canadian Field-Naturalist* 119: 202–207. <https://doi.org/10.22621/cfn.v119i2.107>
- Christie, K. S., and T. E. Reimchen.** 2008. Presence of salmon increases passerine density on Pacific North-west streams. *Auk* 125: 51–59. <https://doi.org/10.1525/auk.2008.125.1.51>
- Coulter, M. C.** 1975. Post-breeding movements and mortality in the Western Gull, *Larus occidentalis*. *Condor* 77: 243–249. <https://doi.org/10.2307/1366220>
- Craine, J. M., E. N. J. Brookshire, M. D. Cramer, N. J. Hasselquist, K. Koba, E. Marin-Spiotta, and L. Wang.** 2015. Ecological interpretations of nitrogen isotope ratios of terrestrial plants and soils. *Plant and Soil* 396: 1–26. <https://doi.org/10.1007/s11104-015-2542-1>
- Craine, J. M., A. J. Elmore, M. P. M. Aida, M. Bustamante, T. E. Dawson, E. A. Hobbie, A. Kahmen, M. C. Mack, K. K. McLauchlan, A. Michelsen, G. B. Nardoto, L. H. Pardo, J. Peñuelas, P. B. Reich, E. A. G. Schuur, W. D. Stock, P. H. Templer, R. A. Virginia, J. M. Welker, and I. J. Wright.** 2009. Global patterns of foliar nitrogen isotopes and their relationships with climate, mycorrhizal fungi, foliar nutrient concentrations, and nitrogen availability. *New Phytologist* 183: 980–992. <https://doi.org/10.1111/j.1469-8137.2009.02917.x>
- Craine, J. M., E. G. Towne, T. W. Ocheltree, and J. B. Nippert.** 2012. Community traitscape of foliar nitrogen isotopes reveals N availability patterns in a tallgrass prairie. *Plant and Soil* 356: 395–403. <https://doi.org/10.1007/s11104-012-1141-7>
- Darimont, C. T., H. Bryan, S. M. Carlson, M. D. Hocking, M. MacDuffee, P. C. Paquet, M. H. H. Price, T. E. Reimchen, J. D. Reynolds, and C. C. Wilmers.** 2010. Salmon for terrestrial protected areas. *Conservation Letters* 3: 379–389. <https://doi.org/10.1111/j.1755-263X.2010.00145.x>
- Darimont, C. T., T. E. Reimchen, and P. C. Paquet.** 2003. Foraging behaviour by gray wolves on salmon streams in coastal British Columbia. *Canadian Journal of Zoology* 81: 349–353. <https://doi.org/10.1139/Z02-246>
- Dawson, T. P., P. R. J. North, S. E. Plummer, and P. J. Curran.** 2003. Forest ecosystem chlorophyll content: implications for remotely sensed estimates of net primary productivity. *International Journal of Remote Sensing* 24: 611–617. <https://doi.org/10.1080/01431160304984>
- Field, R. D., and J. D. Reynolds.** 2013. Ecological links between salmon, large carnivore predation, and scavenging birds. *Journal of Avian Biology* 44: 9–16. <https://doi.org/10.1111/j.1600-048X.2012.05601.x>
- Finney, B. P., I. Gregory-Eaves, M. S. V. Douglas, and J. P. Smol.** 2002. Fisheries productivity in the northeastern Pacific Ocean over the past 2,200 years. *Nature* 416: 729–733. <https://doi.org/10.1038/416729a>
- Fry, B.** 2006. *Stable Isotope Ecology*. Springer-Verlag, New York, New York, USA.
- Fujiwara, M., and R. C. Highsmith.** 1997. Harpacticoid copepods: potential link between inbound adult salmon and outbound juvenile salmon. *Marine Ecology Progress Series* 158: 205–216. <https://doi.org/10.3354/meps158205>
- Gende, S. M., A. E. Miller, and E. Hood.** 2007. The effects of salmon carcasses on soil nitrogen pools in a riparian forest of southeastern Alaska. *Canadian Journal of Forest Research* 37: 1194–1202. <https://doi.org/10.1139/X06-318>
- Gende, S. M., T. P. Quinn, M. E. Willson, R. Heintz, and T. M. Scott.** 2004. Magnitude and fate of salmon-derived nutrients and energy in a coastal stream ecosystem. *Journal of Freshwater Ecology* 19: 149–160. <https://doi.org/10.1080/02705060.2004.9664522>
- Gilbert, B. K., and R. M. Lanner.** 1995. Energy, diet selection and restoration of brown bear populations. Pages 231–240 in *Density-dependent Population Regulation of Black*,

- Brown, and Polar Bears. Proceedings of the 9th International Conference on Bear Research and Management. Edited by M. Taylor and D. L. Garshelis. International Association for Bear Research and Management, Missoula, Montana, USA.
- Goodbrod, J. R., and M. L. Goff.** 1990. Effects of larval population density on rates of development and interactions between two species of *Chrysomya* (Diptera: Calliphoridae) in laboratory culture. *Journal of Medical Entomology* 27: 338–343. <https://doi.org/10.1093/jmedent/27.3.338>
- Gresh, T., J. Lichatowich, and P. Schoonmaker.** 2000. An estimation of historic and current levels of salmon production in the northeast Pacific ecosystem: evidence of a nutrient deficit in the freshwater systems of the Pacific Northwest. *Fisheries* 25: 15–21. [https://doi.org/10.1577/1548-8446\(2000\)025<0015:AE0HAC>2.0.CO;2](https://doi.org/10.1577/1548-8446(2000)025<0015:AE0HAC>2.0.CO;2)
- Harding, J. M. S., M. R. Segal, and J. D. Reynolds.** 2015. Location is everything: evaluating the effects of terrestrial and marine resource subsidies on an estuarine bivalve. *PLoS ONE* 10(5): e0125167. <https://doi.org/10.1371/journal.pone.0125167>
- Heaton, V., C. Moffatt, and T. Simmons.** 2014. Quantifying the temperature of maggot masses and its relationship to decomposition. *Journal of Forensic Sciences* 59: 676–682. <https://doi.org/10.1111/1556-4029.12396>
- Helfield, J. M., and R. J. Naiman.** 2001. Effects of salmon-derived nitrogen on riparian forest growth and implications for stream productivity. *Ecology* 82: 2403–2409. <https://doi.org/10.2307/2679924>
- Helfield, J. M., and R. J. Naiman.** 2006. Keystone interactions: salmon and bear in riparian forests of Alaska. *Ecosystems* 9: 167–180. <https://doi.org/10.1007/s10021-004-0063-5>
- Hilderbrand, G. V., S. D. Farley, T. A. Hanley, C. C. Schwartz, and C. T. Robbins.** 2004. Importance of salmon to wildlife: implications for integrated management. *Ursus* 15: 1–9. [https://doi.org/10.2192/1537-6176\(2004\)015<0001:IOSTWI>2.0.CO;2](https://doi.org/10.2192/1537-6176(2004)015<0001:IOSTWI>2.0.CO;2)
- Hilderbrand, G. V., S. D. Farley, C. T. Robbins, T. A. Hanley, K. Titus, and C. Servheen.** 1996. Use of stable isotopes to determine diets of living and extinct bears. *Canadian Journal of Zoology* 74: 2080–2088. <https://doi.org/10.1139/z96-236>
- Hilderbrand, G. V., T. A. Hanley, C. T. Robbins, and C. C. Schwartz.** 1999. Role of brown bears (*Ursus arctos*) in the flow of marine nitrogen into a terrestrial ecosystem. *Oecologia* 121: 546–550. <https://doi.org/10.1007/s004420050961>
- Hocking, M. D., and T. E. Reimchen.** 2002. Salmon-derived nitrogen in terrestrial invertebrates from coniferous forests of the Pacific Northwest. *BioMed Central Ecology* 2: 4–14. <https://doi.org/10.1186/1472-6785-2-4>
- Hocking, M. D., and T. E. Reimchen.** 2006. Consumption and distribution of salmon (*Oncorhynchus* spp.) nutrients and energy by terrestrial flies. *Journal of Fisheries and Aquatic Sciences* 63: 2076–2086. <https://doi.org/10.1139/F06-110>
- Hocking, M. D., and T. E. Reimchen.** 2009. Salmon species, density and watershed size predict magnitude of marine enrichment in riparian food webs. *Oikos* 118: 1307–1318. <https://doi.org/10.1111/j.1600-0706.2009.17302.x>
- Hocking, M. D., and J. D. Reynolds.** 2011. Impacts of salmon on riparian plant diversity. *Science* 331: 1609–1612. <https://doi.org/10.1126/science.1201079>
- Hocking, M. D., and J. D. Reynolds.** 2012. Nitrogen uptake by plants subsidized by Pacific salmon carcasses: a hierarchical experiment. *Canadian Journal of Forest Research* 42: 908–917. <https://doi.org/10.1139/X2012-045>
- Hocking, M. D., R. A. Ring, and T. E. Reimchen.** 2009. The ecology of terrestrial invertebrates on Pacific salmon carcasses. *Ecological Research* 24: 1091–1100. <https://doi.org/10.1007/s11284-009-0586-5>
- Holtgrieve, G. W., D. E. Schindler, and P. K. Jewett.** 2009. Large predators and biogeochemical hotspots: brown bear (*Ursus arctos*) predation on salmon alters nitrogen cycling in riparian soils. *Ecological Research* 24: 1125–1135. <https://doi.org/10.1007/s11284-009-0591-8>
- Jauquet, J., N. Pittman, J. A. Heinis, S. Thompson, N. Tatyama, and C. J. Cederholm.** 2003. Observations of chum salmon consumption by wildlife and changes in water chemistry at Kennedy Creek during 1997–2000. Pages 71–88 in *Nutrients in Salmonid Ecosystems: Sustaining Production and Biodiversity*. Edited by J. G. Stockner. American Fisheries Society Symposium 34, Bethesda, Maryland, USA.
- Johnson, S. P., and D. E. Schindler.** 2009. Trophic ecology of Pacific salmon (*Oncorhynchus* spp.) in the ocean: a synthesis of stable isotope research. *Ecological Research* 24: 855–863. <https://doi.org/10.1007/s11284-008-0559-0>
- Juen, A., and M. Traugott.** 2007. Revealing species-specific trophic links in soil food webs: molecular identification of scarab predators. *Molecular Ecology* 16: 1545–1557. <https://doi.org/10.1111/j.1365-294X.2007.03238.x>
- Kauffman, J. B., R. L. Beschta, N. Otting, and D. Lytjen.** 1997. An ecological perspective of riparian and stream restoration in the western United States. *Fisheries* 22: 12–24. [https://doi.org/10.1577/1548-8446\(1997\)022<0012:AE PORA>2.0.CO;2](https://doi.org/10.1577/1548-8446(1997)022<0012:AE PORA>2.0.CO;2)
- Klinka, D. R., and T. E. Reimchen.** 2002. Nocturnal and diurnal foraging behaviour of Brown Bears (*Ursus arctos*) on a salmon stream in coastal British Columbia. *Canadian Journal of Zoology* 80: 1317–1322. <https://doi.org/10.1139/Z02-123>
- Klinka, D., and T. E. Reimchen.** 2009. Adaptive coat colour polymorphism in the Kermode Bear of coastal British Columbia. *Biological Journal of the Linnean Society* 98: 479–488. <https://doi.org/10.1111/j.1095-8312.2009.01306.x>
- Lack, D.** 1966. *Population Studies of Birds*. Oxford University Press, London, United Kingdom.
- Lackey, R. T.** 2003. Nutrient addition to restore salmon runs: considerations for developing environmental protection policies and regulations. Pages 283–285 in *Nutrients in Salmonid Ecosystems: Sustaining Production and Biodiversity*. Edited by J. G. Stockner. American Fisheries Society Symposium 34, Bethesda, Maryland, USA.
- Littke, K. M., R. B. Harrison, D. Zabowski, and D. G. Briggs.** 2014. Assessing nitrogen fertilizer response of coastal Douglas-fir in the Pacific Northwest using a paired-tree experimental design. *Forest Ecology and Management* 330: 137–143. <https://doi.org/10.1016/j.foreco.2014.07.008>
- Marshall, D. E., R. F. Brown, G. A. Buxton, V. D. Chahley, and D. G. Demontier.** 1978. Preliminary catalogue of salmon streams and spawning escapements of Statistical Area 2E (Queen Charlotte Islands). Fisheries and Marine Service Data Report #72. Enhancement Services Branch, Fisheries and Marine Service, Department of Fisheries and Oceans and Environment, Vancouver, British Columbia, Canada.

- Mathewson, D., M. H. Hocking, and T. E. Reimchen. 2003. Nitrogen uptake in riparian plant communities across a sharp ecological boundary of salmon density. *BioMed Central Ecology* 2003 3: 4. <https://doi.org/10.1186/1472-6785-3-4>
- McGaw, I. J. 2005. Burying behaviour of two sympatric crab species: *Cancer magister* and *Cancer productus*. *Scientia Marina* 69: 375–381. <https://doi.org/10.3989/scimar.2005.69n3375>
- Meehan, E. P., E. E. Seminet-Reneau, and T. P. Quinn. 2005. Bear predation on Pacific salmon facilitates colonization of carcasses by fly maggots. *The American Midland Naturalist* 153: 142–151. [https://doi.org/10.1674/0003-0031\(2005\)153\[0142:BPOPSF\]2.0.CO;2](https://doi.org/10.1674/0003-0031(2005)153[0142:BPOPSF]2.0.CO;2)
- Nadelhoffer, K. J., and B. Fry. 1994. Nitrogen isotope studies in forest ecosystems. Pages 22–44 in *Stable Isotopes in Ecology and Environmental Science*. Edited by K. Lajtha and R. H. Michener. Blackwell Scientific, Boston, Massachusetts, USA.
- Nagasaka, A., Y. Nagasaka, K. Ito, T. Mano, M. Yamanaka, A. Katayama, Y. Sato, A. L. Grankin, A. I. Zdorikov, and G. A. Boronov. 2006. Contributions of salmon-derived nitrogen to riparian vegetation in the northwest Pacific region. *Journal of Forest Research* 11: 377–382. <https://doi.org/10.1007/s10310-006-0226-7>
- Naiman, R. J., J. M. Helfield, K. K. Bartz, D. C. Drake, and J. M. Honea. 2009. Pacific salmon, marine-derived nutrients, and the characteristics of aquatic and riparian ecosystems. *American Fisheries Society Symposium* 69: 395–425.
- Nakajima, M., and T. Ito. 2003. Aquatic animal colonization of chum salmon carcasses in Hokkaido, northern Japan. *American Fisheries Society Symposium* 34: 89–97.
- O'Keefe, T. C., and R. T. Edwards. 2003. Evidence for hyporheic transfer and removal of marine-derived nutrients in a sockeye stream in southwest Alaska. Pages 99–107 in *Nutrients in Salmonid Ecosystems: Sustaining Production and Biodiversity*. Edited by J. G. Stockner. American Fisheries Society Symposium 34. Bethesda, Maryland, USA.
- Pielou, E. C. 1991. *After the Ice Age: The Return of Life to Glaciated North America*. University of Chicago Press, Chicago, Illinois, USA.
- Quamme, D. L., and P. A. Slaney. 2003. The relationship between nutrient concentration and stream insect abundance. Pages 163–175 in *Nutrients in Salmonid Ecosystems: Sustaining Production and Biodiversity*. Edited by J. G. Stockner. American Fisheries Society Symposium 34. Bethesda, Maryland, USA.
- Ranalli, A. J., and D. L. Macalady. 2010. The importance of the riparian zone and in-stream processes in nitrate attenuation in undisturbed and agricultural watersheds—A review of the scientific literature. *Journal of Hydrology* 389: 406–415. <https://doi.org/10.1016/j.jhydrol.2010.05.045>
- Reimchen, T. E. 1992. Mammal and bird utilization of adult salmon in stream and estuarine habitats at Bag Estuary, Moresby Island. Canadian Wildlife Service, Queen Charlotte City, British Columbia, Canada.
- Reimchen, T. E. 1994. Further studies of black bear and chum salmon in stream and estuary habitats at Bag Harbour, Gwaii Haanas. Canadian Parks Service, Queen Charlotte City, British Columbia, Canada.
- Reimchen, T. E. 1998. Nocturnal foraging behaviour of Black Bears, *Ursus americanus*, on Moresby Island, British Columbia. *Canadian Field-Naturalist* 112: 446–450. Accessed 10 April 2018. <https://www.biodiversitylibrary.org/item/106776#page/462/mode/1up>
- Reimchen, T. E. 2000. Some ecological and evolutionary aspects of bear-salmon interactions in coastal British Columbia. *Canadian Journal of Zoology* 78: 448–457. <https://doi.org/10.1139/z99-232>
- Reimchen, T. E., and C. H. Fox. 2013. Fine-scale spatiotemporal influences of salmon on growth and nitrogen signatures of Sitka spruce tree rings. *BioMed Central Ecology* 2013 13: 38. <https://doi.org/10.1186/1472-6785-13-38>
- Reimchen, T. E., D. Mathewson, M. D. Hocking, J. Moran, and D. Harris. 2003. Isotopic evidence for enrichment of salmon-derived nutrients in vegetation, soil and insects in riparian zones in coastal British Columbia. Pages 59–69 in *Nutrients in Salmonid Ecosystems: Sustaining Production and Biodiversity*. Edited by J. G. Stockner. American Fisheries Society Symposium 34. Bethesda, Maryland, USA.
- Rieman, B. E., C. L. Smith, R. J. Naiman, G. T. Ruggerone, C. C. Wood, N. Huntly, E. N. Merrill, J. R. Alldredge, P. A. Bisson, J. Congleton, K. D. Fausch, C. Levings, W. Pearcy, D. Scarnecchia, and P. Smouse. 2015. A comprehensive approach for habitat restoration in the Columbia Basin. *Fisheries* 40: 124–135. <https://doi.org/10.1080/03632415.2015.1007205>
- Shean, B. S., L. Messinger, and M. Papworth. 1993. Observations of differential decomposition on sun exposed v. shaded pig carrion in coastal Washington State. *Journal of Forensic Sciences* 38: 938–949. <https://doi.org/10.1520/JFS13492J>
- Slaney, P. A., and A. D. Marten. 1997. The watershed restoration program of British Columbia: accelerating natural recovery processes. *Water Quality Research Journal of Canada* 32: 325–346.
- Slaney, P. A., B. R. Ward, and J. C. Wightman. 2003. Experimental nutrient addition to the Keogh River and application for the Salmon River in coastal British Columbia. Pages 111–126 in *Nutrients in Salmonid Ecosystems: Sustaining Production and Biodiversity*. Edited by J. G. Stockner. American Fisheries Society Symposium 34. Bethesda, Maryland, USA.
- Stalmaster, M. V., and J. A. Gessaman. 1982. Food consumption and energy requirements of captive Bald Eagles. *Journal of Wildlife Management* 46: 646–654. <https://doi.org/10.2307/3808555>
- Stockner, J. G., and J. I. Ashley. 2003. Salmon nutrients: closing the circle. Pages 3–15 in *Nutrients in Salmonid Ecosystems: Sustaining Production and Biodiversity*. Edited by J. G. Stockner. American Fisheries Society Symposium 34. Bethesda, Maryland, USA.
- Thomas, S. C., C. B. Halpern, D. A. Falk, D. A. Liguori, and K. A. Austin. 1999. Plant diversity in managed forests: understory responses to thinning and fertilization. *Ecological Applications* 9: 864–879. [https://doi.org/10.1890/1051-0761\(1999\)009\[0864:PDIMFU\]2.0.CO;2](https://doi.org/10.1890/1051-0761(1999)009[0864:PDIMFU]2.0.CO;2)
- Thorne, R. E., G. L. Thomas, and M. A. Bishop. 2006. Alternative seafood waste disposal procedures for Alaskan waters. *Oceans* 14: 49–52. <https://doi.org/10.1109/OCEANS.2006.306979>
- Waring, R. H., and J. F. Franklin. 1979. Evergreen coniferous forests of the Pacific Northwest. *Science* 204: 1380–1386. <https://doi.org/10.1126/science.204.4400.1380>
- Wilkinson, C. E., M. H. Hocking, and T. E. Reimchen. 2005. Uptake of salmon-derived nitrogen by mosses and liverworts in Coastal British Columbia. *Oikos* 108: 85–98. <https://doi.org/10.1111/j.0030-1299.2005.13277.x>

- Willson, M. F., and K. C. Halupka.** 1995. Anadromous fish as keystone species in vertebrate communities. *Conservation Biology* 9: 489–497. <https://doi.org/10.1046/j.1523-1739.1995.09030489.x>
- Wipfli, M. S., J. P. Hudson, J. P. Caouette, and D. T. Chaloner.** 2003. Marine subsidies in freshwater ecosystems: salmon carcasses increase the growth rates of stream-resident salmonids. *Transactions of the American Fisheries Society* 132: 371–381. [https://doi.org/10.1577/1548-8659\(2003\)132<0371:MSIFES>2.0.CO;2](https://doi.org/10.1577/1548-8659(2003)132<0371:MSIFES>2.0.CO;2)
- Yoder, B. J., and R. E. Pettigrew-Crosby.** 1995. Predicting nitrogen and chlorophyll content and concentrations from reflectance spectra (400–2500 nm) at leaf and canopy scales. *Remote Sensing of Environment* 53: 199–211. [https://doi.org/10.1016/0034-4257\(95\)00135-N](https://doi.org/10.1016/0034-4257(95)00135-N)

Received 28 June 2017

Accepted 29 January 2018

Effects of Nesting Bald Eagles (*Haliaeetus leucocephalus*) on Behaviour and Reproductive Rates in a Great Blue Heron (*Ardea herodias*) Colony in Ontario

BILL THOMPSON

93 Donald Street, Barrie, Ontario L4N 1E6 Canada; email: thompsonbi@rogers.com

Thompson, Bill. 2017. Effects of nesting Bald Eagles (*Haliaeetus leucocephalus*) on behaviour and reproductive rates in a Great Blue Heron (*Ardea herodias*) colony in Ontario. Canadian Field-Naturalist 131(4): 369–371. <https://doi.org/10.22621/cfn.v131i4.1848>

Bald Eagles (*Haliaeetus leucocephalus*) and Great Blue Herons (*Ardea herodias*) are known to occasionally nest in mixed colonies, even though the former is one of the primary predators of the latter. I observed the two species in four heron colonies near Lake Simcoe, Ontario during two field seasons to assess whether rates of heron chick mortality or nest abandonment were greater in a colony that supported a nesting pair of Bald Eagles than in three nearby single-species colonies. I assessed the effects of eagle presence on heron behaviour using heron movement rates, the number of heron sentries left in colonies during the nesting period, heron nest mortality rates, and the average number of successfully fledged herons per nest. There was no statistically significant difference in movement rate among the four colonies, proportion of birds remaining as sentries, nor nest mortality rates. However, nests in the mixed colony successfully fledged significantly more heron young per nest than did nests in the single-species colonies. The mixed colony was located in a wetland and open lake system that provided extensive foraging habitat and an abundance of the preferred fish prey species of both Great Blue Herons and Bald Eagles, thus reducing predation pressure on the herons.

Key Words: Lake Simcoe; colonial nesting bird; reproduction; nest predation

Introduction

Bald Eagle (*Haliaeetus leucocephalus*) numbers have been increasing in the Great Lakes basin since the 1980s (Steenhof *et al.* 2002; Eakle *et al.* 2015), leading to its delisting as a species at risk in both the United States (Eakle *et al.* 2015) and Ontario (Armstrong 2014). While this is a conservation success, there may be impacts on other wildlife species.

Bald Eagles sometimes nest in Great Blue Heron (*Ardea herodias*) colonies and are known to prey upon Great Blue Heron adults, young, and eggs (Gostomski and Matteson 1999; Vennesland and Butler 2011). In British Columbia, where Great Blue Heron populations have been rapidly increasing, the occurrence of co-nesting eagles has also been increasing (Jones *et al.* 2013), and eagle predation may be one of the most significant factors lowering heron productivity (e.g., Norman *et al.* 1989; Vennesland 1996; Vennesland and Butler 2004). Great Blue Herons nesting in the Strait of Georgia responded more to the presence of eagles than to any other predator, and eagles were responsible for the majority of documented nesting failures, either through direct predation or because of colony abandonment (Vennesland 1996; Vennesland and Butler 2004; Van Damme and Colonel 2007). While previous studies of the interactions between these two species at heron colonies have been conducted in British Columbia, co-nesting of the two species is widespread (though uncommon) across North America (Gostomski and Matteson 1999), and perhaps increasing.

More Great Blue Herons live in the Great Lakes basin than in British Columbia (Vennesland and Butler 2011), but colony size tends to be smaller (Graham *et al.* 1996; Vennesland and Butler 2004). Herons nesting in small colonies may be more subject to predation by eagles (Caldwell 1986), which suggests that a continued increase in Bald Eagle populations in the Great Lakes basin could lead to reductions in Great Blue Heron populations, through predation or colony abandonment or both.

The objective of this study was to assess whether the presence of Bald Eagles led to higher rates of heron chick mortality or nest abandonment.

Methods

I conducted weekly surveys of four heron colonies near Lake Simcoe, Ontario (44.4°N, 79.35°W) in 2014 and 2015. The heronries included one where a pair of Bald Eagles had been nesting for at least three successive years (near Keswick) and three with no recent records of nesting eagles (near Barrie, Carden, and Lagoon City). The four colonies were 21–61 km from each other. Surveys were conducted from heron arrival in the second week of April until heronry abandonment (defined as three weeks with no nesting herons observed), or the end of the nesting season.

I made observations from a vantage point (80–300 m) that maximized nest visibility with no evidence of disturbance to the colony. To reduce disturbance at Keswick, I surveyed only the 20 nests within 50 m of the

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalists' Club.

eagle nest. At the outset of each observation period I recorded the number of heron adults and nestlings in the colony and the number of active nests. Over 60 min I recorded heron and eagle movements, including the time at which each individual entered or exited the colony or moved to a different tree in the colony. Any interactions between herons and potential predators (including eagles) were noted, as was any evidence of food being brought to a nest by either species.

I defined movement rate as the number of times a heron entered, exited, or moved within a colony during the observation period divided by the number of adult herons present. I further defined the number of sentries left in the colony as the minimum percentage of nests that included an adult standing at or near a nest during each observation period. I defined mortality rate as the number of nestlings in the colony dying between observation periods, divided by the number of days between observations (Mayfield 1975). Success was identified when fledglings were observed flying.

I tested each variable for normality (Shapiro and Wilk 1965), and log-transformed those (productivity, mortality rate, and movement rate) that were significantly non-normal ($P < 0.05$). The effects of sharing a colony with eagles on each of these response variables were tested using analysis of variance (ANOVA). When significant differences were found among the four colonies, orthogonal contrasts were used to determine if the mixed colony was significantly different than the single-species colonies. All the analyses were done using R (R Core Team 2015).

Results

The Keswick colony had at least 64 nesting heron pairs and one nesting pair of eagles in a tree adjacent to some of the heron nests. Lagoon City had eight heron pairs, Barrie three, and Carden three. The Carden colony was abandoned by 15 June 2014 (prior to any evidence of hatching) and was not active in 2015. The four colonies were occupied by herons by the second week in April, whereas eagles began nesting at Keswick in February. At Keswick, one or both eagles were observed on their nest or on a perch in the colony during at least part of every observation period (except once per year). In five observation periods, one or both eagles flew over heron nests, either to act as sentries for their own nest or to travel between the nest and the lake. Herons never responded to the eagles by relocating among nests to protect nestlings, and in only one case did a sentry heron make an alarm call due to the proximity of an eagle. At Lagoon City, however, I observed a subadult (second-year) eagle hunting heron nestlings on 31 May. As the eagle circled the uppermost nest three times with talons extended, two adult herons in the nest made alarm calls with their beaks extended and lunged at the eagle. After the eagle abandoned the hunt, one of the herons flew to a different

nest. No other evidence of attempted predation by other species was observed in any of the colonies.

No statistically significant difference in movement rate was found among the four colonies ($F_{3,27} = 0.915$, $P = 0.45$). However, Keswick herons often traded places: when a heron returned to the colony after foraging, a second heron from a nearby nest would leave the colony within one or two minutes, suggesting that the herons ensured that sentries remained at the colony to protect it from eagle predation. I did not observe this behaviour at the three other colonies. However, there was no significant difference in the minimum proportion of nests with adults present among colonies ($F_{2,19} = 0.801$, $P = 0.46$).

Predation and other disturbance may have easily occurred while I was not observing. There was, however, no significant difference in mortality rates among the three colonies that were not abandoned ($F_{2,19} = 2.194$, $P = 0.14$). Nor was there a significant difference in the proportion of nests abandoned in colonies shared with Bald Eagles, and single-species colonies ($F_{1,5} = 0.342$, $P = 0.58$). However, the Keswick colony fledged significantly more young per nest than the single-species colonies ($F_{2,19} = 17.76$, $P < 0.0001$).

Discussion

Productivity rates in Great Blue Herons typically range from 0.5 to 2.7 fledglings per nest attempt (Vennesland and Butler 2011). In my study area, it ranged from 1 to 2.5 per nest, with the highest rate occurring at Keswick. A rate of 1.91 has been estimated to be required to maintain a stable population (Henny and Bethers 1971). In the current study, only Keswick had a rate this high. It was also the largest of the four colonies studied, and other authors have also found that large colonies tend to support greater productivity (Forbes *et al.* 1985; Vennesland and Butler 2004). Large colonies may be more productive due to a higher ratio of older birds (Forbes *et al.* 1985), or because they tend to be located near larger or more productive foraging habitat (Gibbs and Kinkel 1997). Great Blue Herons typically forage in water between 15 and 25 cm deep (Willard 1977) and they tend to prefer prey between 2.5 and 7.6 cm long during the breeding season (Willard 1977). The Keswick colony is located in a wetland and open lake system that provides over 5.5 km² of such habitat, and supports a fish community with abundant small fishes (e.g., Emerald Shiner [*Notropis atherinoides*], Spottail Shiner [*N. hudsonius*], and Trout-perch [*Percopsis omiscomaycus*]; Evans *et al.* 1996; Trumpickas *et al.* 2012).

There is a potential reproductive trade-off between access to abundant food resources and increased disturbance or predation in co-located Great Blue Heron colonies and Bald Eagle nests. In other locations, Bald Eagles can be predators of Great Blue Herons (Norman *et al.* 1989; Gostomski and Matteson 1999; Vennesland and Butler 2011). In the Keswick colony, however,

there were no occurrences of depredation by eagles, and limited evidence for behavioural response to the presence of a nesting pair of eagles during 23 hours of observation.

The preferred food source for Bald Eagles varies among habitats (Vennesland and Butler 2011), but in the Great Lakes basin it includes species such as Brown Bullhead (*Ameiurus nebulosus*) and White Sucker (*Catostomus commersonii*; Todd *et al.* 1982; Kozie and Anderson 1991), both of which are abundant in Lake Simcoe (Evans *et al.* 1996). Over the course of the 80 hours of observation in this study, three occurrences of Bald Eagles bringing food to nestlings were observed; in all three cases, the food item was a fish. Thus, in this study area, Lake Simcoe may provide enough of an alternate food source for eagles, reducing predation pressure on nesting herons—a species that will actively defend itself and its young.

Acknowledgements

Thanks to Dwayne Lepitzki, Jon McCracken, and two anonymous reviewers, whose comments immeasurably improved the quality of this report.

Literature Cited

- Armstrong, E. R. 2014. Management plan for the Bald Eagle (*Haliaeetus leucocephalus*) in Ontario. Ontario Management Plan Series. Prepared for the Ontario Ministry of Natural Resources and Forestry, Peterborough, Ontario, Canada.
- Caldwell, G. S. 1986. Predation as a selective force on foraging herons: effects of plumage color and flocking. *The Auk* 103: 494–505.
- Eakle, W. L., L. Bond, M. R. Fuller, R. A. Fischer, and K. Steenhof. 2015. Wintering Bald Eagle count trends in the conterminous United States, 1986–2010. *Journal of Raptor Research* 49: 259–268. <https://doi.org/10.3356/JRR-14-86.1>
- Evans, D. O., K. H. Nicholls, Y. C. Allen, and M. J. McMurtry. 1996. Historical land use, phosphorus loading, and loss of fish habitat in Lake Simcoe, Canada. *Canadian Journal of Fisheries and Aquatic Sciences* 53: 194–218. <https://doi.org/10.1139/196-012>
- Forbes, L. S., K. Simpson, J. P. Kelsall, and D. R. Flook. 1985. Reproductive success of Great Blue Herons in British Columbia. *Canadian Journal of Zoology* 63: 1110–1113. <https://doi.org/10.1139/z85-167>
- Gibbs, J. P., and L. K. Kinkel. 1997. Determinants of the size and location of Great Blue Heron colonies. *Colonial Waterbirds* 20: 1–7. <https://doi.org/10.2307/1521757>
- Gostomski, T. J., and S. W. Matteson. 1999. Bald Eagles nest in heron rookery in the Apostle Islands. *The Passenger Pigeon* 61: 155–159.
- Graham, K., B. Collier, M. Bradstreet, and B. Collins. 1996. Great Blue Heron (*Ardea herodias*) populations in Ontario: data from and insights on the use of volunteers. *Colonial Waterbirds* 19: 39–44. <https://doi.org/10.2307/1521805>
- Henny, C. J., and M. R. Bethers. 1971. Population ecology of the Great Blue Heron with special reference to western Oregon. *Canadian Field-Naturalist* 85: 205–209. Accessed 10 April 2018. <https://www.biodiversitylibrary.org/item/89145#page/229/mode/1up>
- Jones, I. M., R. W. Butler, and R. C. Ydenberg. 2013. Recent switch by the Great Blue Heron, *Ardea herodias fannini*, in the Pacific northwest to associative nesting with Bald Eagles (*Haliaeetus leucocephalus*) to gain predator protection. *Canadian Journal of Zoology* 91: 489–495. <https://doi.org/10.1139/cjz-2012-0323>
- Kozie, K. D., and R. K. Anderson. 1991. Productivity, diet, and environmental contaminants in bald eagles nesting near the Wisconsin shoreline of Lake Superior. *Archives of Environmental Contamination and Toxicology* 20: 41–48. <https://doi.org/10.1007/BF01065326>
- Mayfield, H. 1975. Suggestions for calculating nest success. *Wilson Bulletin* 87: 456–466.
- Norman, D. M., A. M. Breault, and I. E. Moul. 1989. Bald Eagle incursions and predation at Great Blue Heron colonies. *Colonial Waterbirds* 12: 215–217. <https://doi.org/10.2307/1521343>
- R Core Team. 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Accessed 31 July 2016. <http://www.R-project.org>
- Shapiro, S. S., and M. B. Wilk. 1965. An analysis of variance test for normality (complete samples). *Biometrika* 52: 591–611. <https://doi.org/10.2307/2333709>
- Steenhof, K., L. Bond, K. K. Bates, and L. L. Leppert. 2002. Trends in midwinter counts of Bald Eagles in the contiguous United States, 1986–2000. *Bird Populations* 6: 21–32.
- Todd, C. S., L. S. Young, R. B. Owen, and F. J. Gramlich. 1982. Food habits of Bald Eagles in Maine. *Journal of Wildlife Management* 46: 636–645. <https://doi.org/10.2307/3808554>
- Trumpickas, J., A. Smith, M. M. Robillard, and J. K. L. La Rose. 2012. Temporal shifts in the biodiversity of nearshore small fishes in Lake Simcoe. *Journal of Great Lakes Research* 38: 643–652. <https://doi.org/10.1016/j.jglr.2012.09.006>
- Van Damme, L. M., and C. Colonel. 2007. Bald Eagle predation and other disturbance factors at Double-crested Cormorant and Great Blue Heron nesting colonies in the Creston Valley. *British Columbia Wildlife Afield* 4: 213–232.
- Vennesland, R. G. 1996. The effects of disturbance from humans and predators on the breeding decisions and productivity of the Great Blue Heron in south-coastal British Columbia. M.Sc. thesis, Simon Fraser University, Burnaby, British Columbia, Canada.
- Vennesland, R. G., and R. W. Butler. 2004. Factors influencing Great Blue Heron nesting productivity on the Pacific Coast of Canada from 1998 to 1999. *Waterbirds* 27: 289–296. [https://doi.org/10.1675/1524-4695\(2004\)027\[0289:FGIBHN\]2.0.CO;2](https://doi.org/10.1675/1524-4695(2004)027[0289:FGIBHN]2.0.CO;2)
- Vennesland, R. G., and R. W. Butler. 2011. Great Blue Heron (*Ardea herodias*). In *The Birds of North America*, Edited by P. G. Rodewald. Cornell Lab of Ornithology, Ithaca, New York, USA. Accessed 31 July 2016. <http://bna.birds.cornell.edu/bna/species/025>
- Willard, D. E. 1977. The feeding ecology and behavior of five species of herons in southeastern New Jersey. *Condor* 79: 462–470. <https://doi.org/10.2307/1367726>

Received 24 August 2016

Accepted 4 January 2018

Book Reviews

Book Review Editor's Note: *The Canadian Field-Naturalist* is a peer-reviewed scientific journal publishing papers on ecology, behaviour, taxonomy, conservation, and other topics relevant to Canadian natural history. In line with this mandate, we review books with a Canadian connection, including those on any species (native or non-native) that inhabits Canada, as well as books covering topics of global relevance, including climate change, biodiversity, species extinction, habitat loss, evolution, and field research experiences.

Currency Codes – CAD Canadian Dollars, USD US Dollars, EUR Euros, AUD Australian Dollars, GBP British Pound.

POETRY

Welcome to the Anthropocene

By Alice Major. 2018. The University of Alberta Press. 136 pages, 19.95 CAD, Paper.

Poets work like naturalists or scientists. What they do is based on what has gone before. Alexander Pope wrote *Essay on Man*, one of the most quoted poems in the English language, in the 18th century. It is in Heroic Couplets, five-beat lines that rhyme AA, BB, CC, and so on. This collection is written in Alberta, in the 21st century. Its title poem, "Welcome to the Anthropocene", has the same metre and rhyme scheme, and uses Pope's poem as a platform for a survey of the world the poet sees.

Pope, writing in the century of Newton, Leibniz, and The Great Chain of Being, could explore his universe and conclude, emphatically, "Whatever is, is right". Alice Major was born in Scotland, grew up in Toronto, has worked in British Columbia, was Poet Laureate of Edmonton, and now lives in Calgary. She writes in the age of quantum physics and climate change, and has her doubts. Pope's heroic couplets march across the page with the regularity dictated by the Laws of Motion, and can tire the reader. Major softens her verse with offbeats and imperfect rhymes:

Nature solves
her vast equations without fuss – the scrawls
of protein folding, evolving puzzles
posed by careering quantum particles.

Pope rebukes some of his contemporaries for the sin of pride. Major explores "post-natural creation":

Welcome, transgenic zebrafish. Your shades
of trademarked colours—*Starburst red*,
Electric Green, and *Cosmic Purple*—bred
to decorate aquariums
in colour schemes to match our rainbow whims.

"Welcome to the Anthropocene" is a long poem, 21 pages. The poet's wry, somewhat sad wit, leavened by her scientific knowledge, comes to a not unhopeful conclusion:

We might not unite
behind Pope's verse *Whatever is, is right*.
Still, whatever is, matters, in a wholeness where
everything is common and everything is rare.

There are a number of other fine poems, of varying lengths, touching a lot of subjects, with influences that seem to range from Gerard Manley Hopkins to a Peterson Field Guide. Major is good at inventing verse forms that suit the material she wants to address. In English poetry there is not likely another poem with a title like this:

Catena
2.71828 1828 4590 4523 5360 2874 7135 2...

There is a note that explains the mathematical significance of the formula, but the poem is a moving meditation on the randomness of genetics and one of the things poetry tries hardest to deal with:

The slowing increments of loss
when it can't get any worse, or
any better. The sad slog up, to stand
on something that approaches solid ground.

A poet living on the prairies can be expected to set some of her poems on farmland. This poet doesn't mind a dirty pun, in "Annual Grains":

Agriculture's pornographic fact:
.....No truly wild plant spends
so much of its energy on sex,
on putting out, on hanging on
to seed heads that should scatter, shatter
small grains into earth's soft box

Major apparently lives in the city though, and works in an office:

hickory dickory click
of computer mice from adjoining cubicles
tick tick-tick tick

The reader will find more mice, but birds are the fauna that have always most attracted poets. There are a lot of birds, including the marvellous corvid that in eastern Canada we don't get:

Magpie as neighbour. You've moved in,
hold your raucous parties, shout at the kids.
Fix up your house – a slipshod DIY
endeavour that always seems half-done. Twigs
strewn all around the yard.

The poet has had fun writing these poems, which is a good sign for the reader. The poems are serious, but the reader can expect to have fun reading them.

The following is excerpted from "Welcome to the Anthropocene" by Alice Major:

Now, welcome to the Anthropocene
you battered, tilting globe. Still you gleam,
a blue pearl on the necklace of the planets.
This home. Clouds, oceans, life forms span it
from pole to pole, within a peel of air
as thin as lace lapped round an apple. Fair
and fragile bounded sphere, yet strangely tough
this world that life could never love enough.
And yet its loving-care has been entrusted
to a feckless species, more invested
in the partial, while the total goes unnoticed.

MURRAY CHRON
Ottawa, ON, Canada

BOTANY

Plant Ecology: Origins, Processes, Consequences. Second Edition

By Paul Keddy. 2017. Cambridge University Press. 624 pages, 74.95 CAD, Cloth, 52.00 USD, E-book.

I was excited to be asked to review this book. In the middle of heavily revising my second-year introductory plant ecology course, I have been wanting for inspiration. Though we have never met in person, Paul Keddy has heavily influenced my academic career. His 2001 book *Competition* was a central influence on my Ph.D. work, particularly the sections on the intensity and importance of competition. While there is much to recommend in this revised plant ecology text book, in the end I came away disappointed.

I will start with the positives. First, and most important, this book is that rare find in the textbook world: an entertaining read. The personal anecdotes and historical digressions are well chosen and add colour and interest. The book is well organized for an instructor. Chapters are built around themes covering first the major biotic and abiotic mechanisms that influence individual plants, then population- and community-level processes. The book is greatly enhanced by the chapters that are not present: missing are the (often endless) chapters on biogeochemical cycles that dominate the first third of many introductory ecology textbooks. Instead, Keddy recognizes that most readers will already be familiar with topics such as elemental cycles, and all that is needed is a succinct summary focussing on important links to plants. Similarly missing is the traditional parade of biomes that invites the memorization of factoid after factoid. Rather, we are presented, only four figures into the book, with the plot first introduced by Whittaker relating the major global biomes to gradients in mean annual temperature and precipitation (p. 6, Figure 1.4). Time and again Keddy returns to that plot as topics such as ecophysiology, disturbance, and herbivory are raised. By the end the attentive reader can reconstruct the core features of any biome from the causal mechanisms. Features like this that invite thoughtful inquiry-based teaching and learning are the best aspects of this book.

Now to the negatives. While the book is entitled "Plant Ecology", it could be perhaps better titled "Paul Keddy's View of Plant Ecology". While the book is marketed as a general textbook, it presents a biased and misleading view of our field. The examples draw far too heavily on Keddy's own research, creating an imbalance in the topics covered and views presented. This is evidenced by 31 citations to work where Keddy is the lead author (and many more to his students' and collaborators' work), while other leaders in our field are rarely mentioned. There are, for example, only three citations to papers led by Tilman and two by Chapin. This trend extends to some sub-topic choices within the book. To cite only one example, two full pages are devoted to the theory of centrifugal community organization while the far more influential work by Grace on multivariate controls of diversity is relegated to only a single citation without comment. A second very significant problem with this book is the currency of the literature. There appears to have been little effort to update the literature between the first (2007) and the second edition. Keddy makes the excellent point that older examples remain valid and should not be discounted. In many cases he is right, yet science has moved forward in the last decade. This is particularly the case in fields where major progress has been driven by advancing technology. How is it acceptable, for example, that a section on mycorrhizae mentions the insights arising from next-generation sequencing only in passing, or that a section on ordination advises readers to consult sources from the 1970s and 1980s? When I see such examples in areas where I am intimately familiar with both the current and older literature, I am left questioning what I am reading in areas where I have read less deeply.

Would I recommend this book? For a Ph.D. student preparing for their comprehensive exam – yes. Keddy provides a broad and engaging summary of much of

the history of plant ecology, a perspective invaluable to an emerging scholar. Would I assign the book to an undergraduate course? No. While this book has much to offer the experienced reader, I fear that an introductory student will be left with an incomplete view of the science of plant ecology.

Literature Cited

Keddy, P. A. 2001. *Competition*. Second Edition. (Population and Community Biology Series). Chapman & Hall, London, United Kingdom.

ERIC LAMB

Department of Plant Sciences, University of Saskatchewan.
Saskatoon, SK, Canada

Exploring the Limestone Barrens of Newfoundland and Labrador

By M. Burzynski, H. Mann, and A. Marceau. 2017. Gros Morne Co-operating Association, Rocky Harbour. 368 pages, 26.95 CAD, Paper.

At least once in their life, every Canadian botanist should do this ... stand in the midst of a silent (but for the wind), forever expanse of seaside limestone barren at the northern tip of the island of Newfoundland. One immediately appreciates that this is like nowhere else in their experience, nor like any other place on this continent. There is a whole lot of Arctic here—the offshore icebergs are a clue—plus a good dollop of Nordic European flavour to the Barrens experience. And of course, there's the omnipresence of the sea. Botanizing this unique rocky landscape with the very real possibility of being interrupted at any time by a breaching Humpback Whale (*Megaptera novaeangliae*) not many metres offshore is extraordinary.

The Barrens are dripping in rare and extraordinary plants growing in a variety of otherworldly habitats. Barrens biota are diverse—surprisingly so for such a northern place (>50°N)—and colourful too. Acres of ladyslippers, milkvetch, gentians, and a myriad of other floristic wonders dominate rocky slopes and low, healthy meadows from wind-swept ridges right down to the sea. It is hard to credit the term “Barrens”, frankly, if you're there at the peak of bloom. Legendary numbers of blackflies are there too—and all too real—but everything comes with a price. And besides, it's always windy!

All of that (perhaps not the blackflies) is beautifully expressed and explained in this terrific field guide. *Exploring the Limestone Barrens* purports to be a natural history guide but, truth be told, it is a botanical guide with beyond-superb introductory chapters explaining the formation and diversity of this rare landscape.

The biogeographically-unique Barrens were made famous initially through the explorations and publications of botanist Merritt Fernald and his associates in the early decades of the 20th century. As *Exploring the Limestone Barrens* explains, these pioneer field naturalists discovered not only a remarkable array of disjunct species from the Arctic, western North America, and even northwestern Europe that had persisted here for thousands of years from post-glacial times, but endemic taxa as well. Many new species were described, particularly within such still-perplexingly complexes

as *Antennaria* and *Astragalus* (there was, as in contemporary times, something of a taxonomic splitting frenzy going on then). A number of these taxa have stood the test of time, however, and are still recognized today.

Botanical ‘stars’ include endemic species such as Fernald's Braya mustard (*Braya fernaldii* Abbe) which can sometimes ‘tower’ as much as 7 cm over Barrens shore alvars but usually does not get much above 2 cm, and the sprawling Barrens Willow (*Salix jejuna* Fernald). ‘Low and sprawling’ is a common theme for plants making a go of it in this daunting landscape of limey, nutrient-poor substrates, very long winters, low light, and constant exposure to wind and sea spray.

Exploring the Limestone Barrens is as colourful as the Barrens in bloom, with hundreds of bright photos providing superb illustrations of a substantial proportion of the flowering plants and ferns of the Barrens species. Comparably high-quality images of representative of non-flower vascular plant groups (sedges, grasses, and rushes) and non-vasculars (bryophytes and lichens) as well as fungi, are also provided. The text provided for each species is spare due to space limitations and the images are small, but in combination they work. A moderately experienced field botanist ‘from away’ should be able to identify pretty much everything they encounter on the Barrens with reference to this small (18 × 11 cm), durable, and jam-packed volume. It is a credit to the Gros Morne Co-operating Association that they were able to produce such a physically attractive and substantial product at such an accessible price.

The greatest compliment I can offer the authors of this guide is that they have honestly reflected and represented the visual beauty, ecological complexity, and wonderful wildness of the Barrens. This guide will inspire you to visit these remarkable landscapes if you have not already done so. If you do, you will be well-served having *Exploring the Limestone Barrens* in your back pocket. And you can even use it to swat blackflies!

DANIEL F. BRUNTON

Ottawa, ON, Canada

Flora of Florida Volume IV (Dicotyledons, Combretaceae through Amaranthaceae)

By R. P. Wunderlin, B. E. Hansen, and A. R. Franck. 2017. University Press of Florida. 384 pages, 69.95 USD, Cloth.

Richard Wunderlin and Bruce Hansen began their comprehensive, multi-volume *Flora of Florida* with the 2000 publication of *Volume I, Pteridophytes and Gymnosperms* (University Press of Florida). When more than a decade passed without another volume appearing, it seemed that the task might have just been too big an order. The publication of Volumes II and III in 2015 importantly demonstrated that the *Flora of Florida* project was indeed alive and well and that plans were underway to see all 10 volumes published by 2020 (see reviews in *The Canadian Field-Naturalist* 130: 248–249). Happily, the publication of Volume IV indicates that progress continues to be made.

Volume IV follows the format and structure of its predecessors, being a sturdily bound, hard-cover book with small but easily-readable type. The native and non-native species of the 31 families are covered, each providing detailed, clear physical descriptions employing precise but not overly technical terminology. No glossary (nor illustrations) are provided although representative generic illustrations are tentatively planned for future volumes (R. Wunderlin, personal communication, 2016).

The number of taxa covered in Volume IV is unstated but using as a measure the species per page coverage of Volume I where that number is provided, it seems there are approximately 450 species discussed here. Volumes I through IV then, now cover about 45% of the over 4000 vascular plants known to occur in Florida. In addition to a significant number of uniquely or predominately southern/tropical plants in groups such as Rutaceae and Melastomataceae, Volume IV includes species treatments of large families that are important and familiar to Canadian botanists, including Polygonaceae, Brassicaceae, Caryophyllaceae, and Onagraceae. This is one of the strengths of the *Flora* for northern users: providing a very different regional perspective on complicated taxa that we struggle with here, like the

Polygonum aviculare L., *Brassica rapa* L., and *Oenothera biennis* L. species complexes. Once again, effective species identification keys taken or updated from Wunderlin's *Guide to the Vascular Plants of Florida* (1998, University Press of Florida) are placed immediately after each genus description. Alphabetically arranged species treatments follow, each beginning with a comprehensively annotated list of synonyms. The thoroughness of synonymy is truly impressive: there are 38 provided for Field Mustard *Brassica rapa* (= *Brassica campestris* L.) alone. These constitute valuable taxonomic/nomenclatural histories that are of use in taxonomic studies anywhere.

I will repeat the same complaint lodged in reviews of Volumes II and III regarding the absence of page headers to identify the family to which that page's treatments apply; such headers would greatly simplify finding particular treatments without frequent reliance on the (thankfully very good) index. The absence of Florida range maps for each taxon reduces the clarity of the broadly expressed distributional statements. However, the online *Atlas of Florida Plants* (<http://florida.plantatlas.usf.edu>) serves this purpose admirably. For the present, at least.

This volume and its companions are important contributions to floristic documentation in North America *per se*, not just in regard to botanical investigations in the third most floristically diverse part of the United States. This window into such an important part of the continental flora is also worthwhile for Canadian studies involving the many species of northern North America that also reach the Deep South. And, of course, *Flora of Florida* is a great resource for serious Canadian botanical "Snow Birds", of which there are a large and growing number.

DANIEL F. BRUNTON

Ottawa, ON, Canada

ZOOLOGY

The Wolf: A True Story of Survival and Obsession in the West

By Nate Blakeslee. 2017. Random House Canada. 320 pages, 32.00 CAD, Cloth, 15.99 CAD, E-book.

The Wolf (published as *American Wolf* in the United States) was a great read about Yellowstone wolves and the political and sociological aspects of wolf recovery in the west. It focussed on a particularly famous female wolf (dubbed "O-Six" for the year she was born) who ruled the Lamar Valley region of the park until her untimely death on 6 December 2012. I related easily to this book because I regularly visit the Yellowstone region and call Rick McIntyre and Laurie Lyman friends. They are the two main human characters in the book in addition to Steven Turnbull (pseudonym), the man who shot and killed O-Six. O-Six was a striking 97-pound

grey-coloured wolf, captured by accident and given a research radio-collar and scientific ID #832.

I had numerous sightings of O-Six on my many trips to the park and regard watching her with my son as one of the most rewarding experiences of my life. Those were mighty special experiences for me, and Nate Blakeslee brings these moments back to life by recounting the enthralling story of the rise and reign of O-Six, a most celebrated Yellowstone wolf. The author goes into depth describing the people who loved her and those who feared her, and focusses on Yellowstone's wolf watchers, led by Rick McIntyre, a park biologist who,

according to Wolf Project leader Doug Smith, is the glue that holds everyone in that community together (p. 265). “Wolf Watchers” is an unofficial group of people who regularly visit (one or twice a year or more) or live near the park, focussing their time looking for and watching wolves interact with other members of Yellowstone’s wild community including Elk (*Cervus canadensis*), bison, bears, Coyotes (*Canis latrans*), foxes, Pronghorns (*Antilocapra americana*), and many other creatures. I try to visit Yellowstone once or twice a year and spend a lot of quality time with Rick and Laurie and other people while watching wolves in a pristine and beautiful environment.

The book is unique in that it focusses on a particular female wolf from Yellowstone but tries to also tie back to some of the larger reasons why people have had such a troubled relationship with wolves. Once abundant in North America, wolves were hunted to near extinction in the lower 48 states by the 1920s (p. 14). In recent decades, Blakeslee notes, conservationists have brought wolves back to the Rockies, igniting a battle over the very soul of the west. Blakeslee uses the O-Six female as a sort of frontline battle between the old guard (people who exterminated wolves and still hate them, both for their ability to kill ungulates like Elk as well as the political interventions that they represent) and the new guard, like the wolf watchers, who appreciate having wolves around.

O-Six was beloved by many, particularly Rick McIntyre. Over the course of her 6.75-year life (2006–2012), she became something of a social media star, with followers around the world. Part of her allure was that thousands of people were privileged to see her and her pack in the wild and watched her raise three litters of pups (2010–2012), protect her pack from Grizzly Bears (*Ursus arctos*) that came near her den, compete with rival wolf packs (sometimes fatally), hunt Elk, and survive in an often-hostile world with cold temperatures, lots of snow, and human hunters waiting at the park’s borders. As noted on the book’s cover-leaf, *The Wolf* is a riveting multigenerational saga of hardship and triumph that tells a larger story about the ongoing cultural clash in the west: between those fighting for a vanishing way of life and those committed to restoring one of the country’s most iconic landscapes. It is fascinating as the book frequently toggles between describing these larger, generational shifts in attitudes towards preserving iconic carnivores like Grey Wolves (*Canis lupus*) to focussing on O-Six and Rick and their personal trials and tribulations. Given that Rick has made over 85 000 wolf sightings (p. 268), aided by radio-telemetry, spotting scopes, and a cadre of wildlife watchers assisting him, it is safe to assume that he has observed more wild wolves than any human in history. His iron man 15-year streak of going into the park every day, including a stint where he saw wolves on 891 straight days (p. 147), is unlikely to be topped.

Many of Blakeslee’s digressions from O-Six and Rick describe the history of wolf recovery, using a thorough literature review as well as film-maker Bob Landis’s four nature documentaries on Yellowstone’s

wolves. This historical information provides perfect background material to make this book a great stand-alone read for novices to Yellowstone wolves.

Interestingly, Blakeslee was also able to track down and meet with the person who shot O-Six east of Yellowstone National Park. They agreed to use the pseudonym Steven Turnbull. I felt that a fair and non-biased description was given of Turnbull. While he leans anti-wolf, he does not claim to particularly hate them like others do in the area; he seemed to have more of a resentment for wolves changing his way of life including part of the reason why there are fewer Elk around Yellowstone. But Turnbull was fascinated with Bob Landis’s videos, watching the one on O-Six (titled *She-Wolf*) multiple times, and showed Blakeslee O-Six’s pelt with admiration. While many in Turnbull’s position have a bitterness for what they perceive as out-of-staters dictating how they need to live (i.e., with wolves), many people (including myself) feel a bit of distain for locals around Yellowstone who feel they have more rights than the average American over our collective vast federal lands. This has brought land disputes and even rebellions all over the west, many of which are described in the book. And wolves are just the latest struggle between insiders and outsiders over control of the vast western United States. Blakeslee does a great job of highlighting these struggles without going too much in depth.

I highly recommend *The Wolf*. Easy-to-read and absorbing, it does a unique job of focussing on individuals—both wolves and humans—yet entertains the bigger, political picture of wolf recovery. Given the number of dedicated wolf watchers discussed at length, many of whom take images of their experiences, I was very surprised there were no pictures of O-Six in the book, even black and white ones. And the main title is pretty generic; it could have better reflected O-Six and the Yellowstone region.

I’d like to conclude with Blakeslee’s thoughts on seeing O-Six’s pelt in Turnbull’s cabin in Crandall, Wyoming: “It was impossible not to think of the countless stories I’d heard about what she’d done with those tireless legs and those formidable teeth, the elk she’d taken down single-handedly, the territorial battles she’d won, the pups she’d reared, the loyalty and love and fear she’d inspired and the enormous and magnificent stage upon which she’d done it all, in front of her thousands of fans” (p. 261). I am proud to call myself one of O-Six’s fans and hope this book helps bring about the recognition of the importance of individual animals, as well as the knowledge of the key ecological role that wild canines play throughout North America. They all have unique stories to tell. Wolves (and other wild canids) are intelligent, sentient, family-oriented animals who deserve much more respect than is currently given by our governments, both state and federal. Don’t believe me? Then read this book and I’m sure you’ll change your mind.

JONATHAN (JON) WAY

Eastern Coyote/Coywolf Research, Osterville, MA, USA

Marine Fishes of Arctic Canada

Edited by Brian W. Coad and James D. Reist. 2017. University of Toronto Press. 632 pages and 200 illustrations, 74.96 CAD, Cloth or E-book.

Thoroughly describing the marine fishes of Arctic Canada is an enormous undertaking. Not only are there many known species (221), but the Arctic marine environment is notoriously difficult to survey owing to the presence of sea ice, remoteness, and the extreme environmental conditions. Many species will therefore be underrepresented in studies owing to small survey effort, and entire regions may be entirely unsampled, especially in the northernmost areas where sea ice never melts. In *Marine Fishes of Arctic Canada*, the authors expertly describe all 221 species of marine fishes that are known in Arctic Canada but, most importantly, acknowledge the data limitations for these species. Unlike other guides that attempt to draw species ranges on maps, this guide simply shows the locations where the species has been found in Arctic Canada and puts it in the context of where the species is found in the rest of the world. These points on the map are a direct acknowledgement of the vast, remote nature of the region and that, with more survey effort, these species may be found in other areas. These 221 species include 37 species that were not previously included in lists of Canadian Arctic marine fishes. The "Checklist of Species" also lists extralimital species that are found adjacent to Canadian Arctic waters, and may be found in the Canadian Arctic with increased survey effort.

The authors also provide impressive details about each species, with more than 400 pages dedicated to species accounts. The amount of information presented for each species is tempered by how common they are in the region and how much they have been studied. For example, 6.5 pages are devoted to Arctic Char (*Salvelinus alpinus*), whereas Threadfin Grenadier (*Gadomus longifilis*) is described in just over one page. While

Arctic Char is found throughout the Canadian Arctic, Threadfin Grenadier has only been observed once in the Canadian Arctic. When applicable, an exhaustive list of common names is included, such as the 57 different names for Arctic Char.

While most of the text is devoted to detailed species accounts, the first 72 pages focus on defining the context of the book, including rationale for the book and history of fisheries research in the Canadian Arctic, providing background information on the Arctic (environment, climate, and habitat), sources of knowledge used in the text (scientific research, traditional ecological knowledge, and fisheries), and information on scientific names, technical terms, and the collection and preservation of specimens. This background information allows the less knowledgeable reader to gain a fuller appreciation of the amount of effort put into this volume and provides important context for the species accounts. Finally, for novice ichthyologists, the authors provide a detailed key for identification of families and species. Not only do they provide good drawings of the species, but they also draw the characteristics being described in the key, which can be very useful for those unfamiliar with fish anatomy.

Overall, *Marine Fishes of Arctic Canada* is an excellent text for anyone interested in detailed accounts of fish in the Canadian Arctic. The guide includes sufficient details and references for serious scientists, but also provides excellent coverage of information for the amateur naturalist or interested lay-person.

WILLIAM D. HALLIDAY

Wildlife Conservation Society Canada, Whitehorse, YT, and
Department of Biology, University of Victoria, Victoria,
BC, Canada.

Encyclopedia of Whales, Dolphins and Porpoises

By Erich Hoyt. 2017. Firefly Books. 300 pages, 49.95 CAD, Cloth.

Written by a British-based, dual-citizen Canadian who is a research scientist, conservationist, and author, the *Encyclopedia of Whales, Dolphins and Porpoises* provides an interesting and beautiful global overview of cetaceans. Part pictorial guide, part research overview, part coffee table book, and part call to action, and brimming with incredibly beautiful photographs showing cetaceans in action, this book will appeal to many readers in its attractive, easy-to-read format.

The reader will learn a great deal. The book contains many interesting facts about this hugely popular yet mystical group of marine mammals. In recounting the history of cetacean research and monitoring, the author emphasized the major progress made with the realiza-

tion that individual animals could be photographed and identified by distinctive species-specific features, such as flukes, dorsal fins, pigmentation patterns, scars, and wounds. This led to great advances in previously difficult areas to research such as migration, distribution, and social behaviour. In a general book such as this obviously not all biological facts can be provided, but it does provide an interesting and sometimes astounding array of biological information. It is quite enlightening how little is still known about some cetacean species, even breeding areas and species taxonomy, and how recently much of the known scientific information has been gathered. It was sobering to learn that almost half of all cetaceans globally are considered

Data Deficient, with insufficient data to determine status. The book is filled with many fascinating and interesting facts on cetacean life history, with the author often sharing insights and observations from his own research. The discussion on Killer Whale (*Orcinus orca*) ecotypes (fish-, mammal- and shark-feeding) was particularly well done.

The author conveys successfully the essence of the breadth and methods of various research approaches used today, such as transect surveys, acoustic studies, and faecal analysis. Consistent with his concerns about conservation, he delved into some detail on the potentially harmful nature of invasive studies, such as satellite tagging, outlining a series of questions for researchers considering whether such research should be conducted.

The book is logically laid out, although the content is not always well organized. Chapters on the shared history of humans and cetaceans, cetacean research, basic biology, conservation, and future prospects bracket three central chapters containing species accounts devoted to the life history and social behaviour of the three main cetacean groups: baleen whales, toothed whales, and dolphins and porpoises. Unfortunately, these latter chapters treat individual species inconsistently and do not cover all species, with no clear rationale for what species are and are not included. These chapters do not always build on information in a logical progression, sometimes beginning with a discussion of a specific species and only later in the chapter describing the general characteristics of that particular group of cetaceans, often within the section for one specific species. This confusion is in part due to the use of extensive insert boxes, often placed in the midst of other accounts. This is especially disruptive when extensive insert boxes (e.g., two pages) have been placed in the midst of text, and even in the midst of sentences. They are usually indistinguishable from regular text except for different colouration; in most cases, it would have been less confusing and more effective to treat the information in the text box as just another sequential section in the chapter. Although these three central chapters account for one-third of the book's length, they are less useful for between-species comparisons than the appendix, which provides consistent information on all 90 currently recognized species of cetaceans, including illustrations and brief but standard summaries of size, habitat, range, diet, social aspects, and conservation status. However, the size comparison charts of the three major cetacean groups at the end of each chapter are very illustrative. Each species in these charts is cross-referenced with the species summary in the appendix; further cross-references linked to those species addressed in the central three chapters would have been useful.

Although the author does an admirable job, it is difficult to produce a book such as this that is suitable for lay readers while also covering the necessary scientific detail. One example would be the discussion on taxonomy, where in one complex paragraph the author tries to describe in overview the relationships between and

among 14 species of baleen whales (Mysticetes) in four families, and 76 species of toothed whales (Odontocetes) comprising the large-, medium-, and small-sized toothed whales, all with examples. Some inadvertent technical language was occasionally introduced with inadequate explanation, e.g., the term "fluid fusion fission societies" is introduced at one point but not actually explained until almost 60 pages later and most fully explained 100 pages on. There is also the occasional inadvertent duplication of information, sometimes in close proximity.

A glossary would have been very helpful, even though most terms are described somewhere in the text. Given the general/overview nature of the book, the absence of referenced citations is perhaps not surprising, although I often found myself wanting to know the source of, or to follow-up on, some specific interesting fact. The list of select references for the main sources used also provides recommended further reading. The index is useful and comprehensive, although the print is very small.

A relatively few apparent errors, inconsistencies, or areas of potential confusion in the species status section were noted. A figure showing the four humpback dolphin species switched identification for two of them. Maui Dolphin was referred to inconsistently as both a population and a subspecies of Hector's Dolphin (*Cephalorhynchus hectori*), perhaps a consequence of its relatively recent recognition as a subspecies. A reference to and a photograph of Antarctic Minke Whale (*Balaenoptera bonaerensis*) were included within the species account for Common Minke Whale (*Balaenoptera acutorostrata*) rather than in a separate section. Although listed by the International Union for Conservation of Nature (IUCN) as Critically Endangered, Baiji (*Lipotes vexillifer*) of the Yangtze River is variously described as "extinct", "considered extinct", "driven to extinction", and, perhaps most accurately, as "probably extinct". The Critically Endangered Vaquita (*Phocoena sinus*) is described as the "most endangered cetacean in the world, the one closest to extinction", a designation that only makes sense if one concludes that Baiji is extinct.

Figures are not numbered, and information on them is often presented out of order relative to the text, often by several pages. In many cases, linking a text description to a specific figure to demonstrate what is being explained would have been helpful. Global distribution maps would have been a very valuable addition for all species. For example, two of five populations of Bowhead Whale (*Balaena mysticetus*) globally are identified as Endangered but with no indication of the location of these populations.

The author quite appropriately places a great deal of emphasis on the conservation of and future prospects for cetaceans. Future challenges facing the world's cetaceans are many, and addressing them will take long-term, dedicated commitment from society as a whole. The future of cetaceans is addressed objectively and

realistically, neither glossing over the challenges and probable upcoming extinctions nor giving in to despair or hopelessness. There are many initiatives underway or proposed that would improve the future prospects for many cetacean species. The author also suggests a number of practical measures people can take to get involved as citizen scientists and “whale savers”. While not all species are treated equally, the plight of some of the most imperilled species is eloquently and evocatively described.

The discussion of conservation issues and challenges is extremely interesting and useful, although not always well organized or easy to find. A specific chapter is devoted to this topic, but the author often delves deeply into conservation status or issues in the midst of the species accounts, creating some confusion over where to look for conservation information. Given the recent spate of deaths of North Atlantic Right Whales (*Eubalaena glacialis*) in Canada, it was disappointing that the book’s discussion of threats to this species concentrated almost solely on USA waters. The IUCN status of ceta-

cean species is inconsistently referenced in the species accounts, being identified for some species but not others; it is, however, consistently referenced in the appendix.

This book is very ambitious in its scope and meets many of its objectives. Comprehensive, colourful, and full of interesting facts, it does an excellent job of showing the diversity of cetaceans around the world and raising awareness of conservation challenges and concerns for their future. It does treat some species in more detail than others, sometimes inconsistently addresses different life history components, and specific information is not always easy to find. However, as an overview to the diversity, ecology, and life history of cetaceans and a summary of major conservation challenges facing them now and into the future, it is an excellent addition to your natural history and conservation library.

TED ARMSTRONG

Thunder Bay, ON, Canada

Great White Shark: Myth and Reality

By Alexandrine Civard-Racinais. Photographs by Patrice Héraud. 2017. Firefly Books. 144 pages, 19.95 CAD, Paper.

I have read many good books by the publisher of this book, but, “Firefly ... your luciferase was low for this one”. This book just did not glow. I read this book in one three-hour stint, making comments in my notebook regarding errors, misleading/difficult text, and contradictions. I filled more than two pages.

The book is divided into three sections: “Portrait of the Great White”, which largely covers the species’ anatomy; “Searching for the Great White”, a description of the conservation efforts, including techniques used to identify and track the sharks; and “Requiem for the Great White?”, which is about the relationship between this fish and humans, from attacks to ecotourism.

It is the first section of the book which dominates my notebook entries; this is not surprising given that (a) there is no indication that the author has any background in anatomy and (b) the reviewer does. However, some responsibility must lie with the publisher who should have had the manuscript reviewed prior to publication. One ludicrous example should suffice. Most bony fishes have gas bladders to help adjust their buoyancy; sharks and their allies do not. Sharks store oil in their livers, and it is this low-density oil which provides one of several mechanisms by which sharks maintain their position in the water column. There is no *pool* of oil, rather it is distributed within the liver’s cells. And yet the author claims, “This oil allows sharks to adjust their buoyancy and move rapidly up and down without expending much energy” (p. 24). Just how

would they do that ... spit out the oil to make them sink? And what could they do to “rapidly move up” ... very quickly synthesize more oil from a denser substrate in their bodies?

One of the themes of the book is to educate the reader that although the Great White Shark (*Carcharodon carcharias*) is a top predator, some of its behaviours (e.g., curiosity) have been misinterpreted as aggression. The author wants to dispel the rhetoric which gives this animal its bad name. Why then, in a caption, does the author refer to the shark as “marauding”, especially when there is no evidence in the picture that the shark is doing anything but swimming?

I found the second and third sections of the book interesting and less riddled with errors. The story of the formation of the Fox Shark Research Foundation and a description of its work was both motivating and satisfying. The research vessel, tools of the trade (shark cages, transmitters, and more), and some of the neighbouring wildlife were nicely described and photographed. The photography is excellent throughout: repetitive (how many jaw-agape photos does one need in a shark book?), but excellent.

This book is easy to read and aesthetically pleasing owing to the copious photographs. It could have been a great book, but unfortunately, just isn’t.

RANDY LAUFF

Department of Biology, St. Francis Xavier University, Antigonish, NS, Canada

The Skeleton Revealed: An Illustrated Tour of the Vertebrates

By Steve Huskey. 2017. Johns Hopkins University Press. 360 pages, 49.95 USD, Cloth or E-book.

This book features beautiful photographs of 200 cleaned, and sometimes incredibly posed, vertebrate skeletons, with the goal to show the reader some of the diversity which exists. Given the subtitle, one would expect to have either near-equal representation across the vertebrates or a selection reflective of the richness of each major group (fishes, amphibians, reptiles, mammals, birds). In other words, half the book would be fishes, then diminishing numbers through birds, reptiles, mammals, and amphibians. Huskey did get the number of illustrated fish to match their proportion of vertebrates in nature, but his bias with snakes skews everything else. And given that a snake skeleton (save for the skull) is about as simple as it gets (skull, followed by tons of vertebrae with ribs, followed by vertebrae without ribs), it's puzzling to see why so many were included, especially when amphibians, mammals, and birds (illustrated by two, ten, and six photographs, respectively), were given such short shrift.

Each photograph is accompanied by an informative species account. In most cases, a description of the animal (intact, not just the skeleton), its habitat, diet, predators, and sometimes a few other interesting topics are covered. Conservation notes are added, with comments on the pet trade and introduced species, for example. These accounts are just long enough to whet one's appetite to learn more. There is no apparent order to the presentation of the species, and this almost allows Huskey to get away with some strategic copy and paste moments in the accounts. For example, for all six chameleons, we read exactly the same thing about their

"hodge-podge of anatomical novelties", their independently moving eyes, their two-thumbbed feet, the prehensile tail, and ballistic tongues. Spitting cobras, triggerfish, and vipers have similarly repeated passages.

The only other text is the short introduction, and it is fine. Although Huskey mentions that dermestid beetles were used to clean the skeletons, a more detailed methodology would have been nice. For example, what treatment was used on the skeletons to make them so shiny and white? How were the cartilaginous skeletons preserved? How were the skeletons rearticulated (especially for those notorious fish skulls)? Are they on display in a museum now? Photographers may want to know how the photographs were made. Were they digitally post-processed?

This book can be compared with *Evolution* (de Panafieu and Gries 2011), a book with equally beautiful photographs of skeletons, one of which was contributed by Huskey. Of the two books, *Evolution* shows a more diverse array of skeletons (including a few invertebrates) and the specimens are organized by topic, usually with a several-page description introducing each topic, which just seems to work better. Nonetheless, *The Skeleton Revealed* is informative, and the photographs are just a pleasure to view.

RANDY LAUFF

Department of Biology, St. Francis Xavier University, Antigonish, NS, Canada

Literature Cited

de Panafieu, J.-B., and P. Gries. 2011. *Evolution. Seven Stories*. Press. New York, New York, USA.

OTHER

Pilgrims of the Air: The Passing of the Passenger Pigeons

By John Wilson Foster. 2014 / 2017. Notting Hill Editions. 230 pages, 14.99 GBP, 29.95 CAD, Cloth.

Pilgrims of the Air is an extended contemplation in the history of ideas, searching out the myriad paths that lead to an understanding of arguably the most famous extinction of an avian species. Scientists still work to puzzle out definitive answers to the questions of why and how the Passenger Pigeon (*Ectopistes migratoria*), once numbering in the billions, could within a century cease to exist. On the surface, it's a well-known tale, but the full understanding has proven and still proves elusive. John Wilson Foster is a man of as many parts as the story he relates, and the esoteric Notting Hill Editions is a curiously appropriate vehicle for the telling of this story. Born in Ireland, educated there and in the United States, Foster taught in Ireland then at the University of British Columbia before returning as profes-

sor emeritus to the National University, Galway. He has been engaged in historical, cultural questions his entire career, authoring several critical studies on Irish politics and culture. But he also has extensive experience as a naturalist and birder in several parts of the world and editor of *Natural History of Ireland* (McGill-Queen's University Press), published in 1997, primary catalysts for this essay.

And it is an essay: Notting Hill Editions specializes in printing non-fiction essays characterized by excellence of writing and, as the press puts it, "the virtues of brevity, soul and wit". The extinction of a species is hardly a source for wit, but brevity (in the best sense) and soul are evident here. Foster has a poet's clear-eyed capacity to collect and summarize numerous themes in

his exploration here, including attitudes toward nature exhibited by the Aboriginal peoples, several tribes of whom held Pigeon Dances (pp. 51ff), and the Europeans, beginning with the Puritans, who came to settle the lands we call the United States of America. Although he dips even further back to Aristotle, his primary focus is on the long, 19th century lead-up to the early 20th century decades during which the Passenger Pigeon disappeared and subsequent attempts to determine what happened. The beginnings of science in America, and especially the history of natural history, are traced through the works of such early naturalist explorers as John Lawson, Mark Catesby, Peter Kalm, and Alexander Wilson. The efforts of these and other men resulted in extensive knowledge of "Pigeon Country" (Chapter 7), and the pigeons did indeed travel the country, true nomads in search of sources of food. Fossil evidence and distribution maps for their favoured mast tree, the beech, and also the oaks, revealed their extensive range. To a degree, asserts Foster, the fate of the birds was tied to the fate of the trees and the heavy deforestation of the colonial period (p. 107).

We are all familiar with the images of Passenger Pigeons blocking the sun for hours as they flew overhead, but Foster provides extensive descriptions of accounts over the years. We learn of the complex patterns of the birds' movements in time and space, their nesting sites, which could cover hundreds of hectares and contain millions of birds, the destruction these sites wreaked on the forests, and, perhaps most curiously, of the habit of males and females taking turns on the nest. This meant that at feeding time, the vast flocks leaving the nests were composed in turn of males and females, which proved a vulnerability in the face of extensive hunting.

And how extensive the hunting was! The most disturbing part of the story is Foster's detailed accounts, in Chapter 9, "Such Dreadful Havock", and Chapter 10, "Flesh and Feathers both for Use and Ease", of the settlers' capacity to kill anything within range of a gun. This went beyond providing food: any romantic notions of the hunter going off in the woods seeking food for his family are dispelled forever by the rapacious, wanton, almost joyous delight in killing for its own sake. Add to this the industrialization of the killing, discussed in Chapter 12, "Things Future and Things Past", the improvements in communication (such as newspapers, railways, and the telegraph) that facilitated year-round

locating and reaching nesting sites and moving the resulting huge loads of birds to processing plants in the cities, coupled with ongoing destruction of habitat as settlement moved west, and the wonder is that Passenger Pigeons lasted as long as they did. Naturalists are not excluded here, their collecting practices coming under scrutiny, although these were minor compared to the almost universal hunting everywhere the pigeons appeared. As pigeon numbers declined, attention turned to other bird species, such as plovers, curlews, and auks, often valued only for their feathers. A telling image is provided of one ornithologist doing some birding in New York City and identifying over 40 species: all from the feathers in ladies' hats (pp. 164–165).

But the ornithologists were slow to pick up on what was happening in the field, their awareness lagging behind the decline of the Passenger Pigeon. Their extinction was difficult to accept and the final passing of captive Martha in 1914 "took ornithologists by surprise and exposed the meagerness of their knowledge" (p. 212). The serious study of Passenger Pigeon natural history was made on the few specimens remaining in captivity. This theme of the ornithologists' belated role opens and closes the book, an instructive reminder of the potential importance of that role and the very human fragility underlying it.

Almost by definition, the essay is a 'popular' medium, in the best sense: a well-written, engaging, thought-provoking, enlightening narrative. Small in dimensions, comfortable in the hand, pleasingly designed, sewn binding including a red-ribbon bookmark, the book is an interesting artifact in itself. Field naturalists will find it of value, especially those with a historical bent. My only criticism is around the back matter: no index or notes, likely standard for Notting Hill, and a list of "Select References" that frequently did not include authors and titles mentioned in the text. I can't resist mentioning one of these, a certain Howitt (p. 114), whose observations of the flight of Passenger Pigeons over Guelph, Ontario, in the 1860s, were recounted in an article published in 1932 in *The Canadian Field-Naturalist* (Howitt 1932).

BARRY COTTAM

Ottawa, ON, Canada

Literature Cited

Howitt, H. 1932. A short history of the Passenger, or wild, Pigeon. *Canadian Field-Naturalist* 47: 27–30. Accessed 23 May 2018. <https://www.biodiversitylibrary.org/item/89295#page/41/mode/1up>.

NEW TITLES

Prepared by Barry Cottam

Please note: Only books marked † Available for review or * Assigned have been received from publishers. All other titles are listed as books of potential interest to subscribers. Please send notice of new books – or copies for review – to the Book Review Editor.

† Available for review * Assigned

Currency Codes – CAD Canadian Dollars, USD US Dollars, EUR Euros, AUD Australian Dollars, GBP British Pound.

BOTANY

***Woody Plants of the Northern Forest: A Photographic Guide.** By Jerry Jenkins. 2018. Cornell University Press. 64 pages, 25.50 USD, Paper.

***Woody Plants of the Northern Forest: Quick Guide.** By Jerry Jenkins. 2018. Cornell University Press. Foldout Chart, 11.95 USD, Paper.

The Hidden Life of Trees: What They Feel, How They Communicate—Discoveries from a Secret World. By Peter Wohlleben. Translated by Jane Billinghurst. Foreword by Tim Flannery. 2018. Greystone Books. 288 pages, 21.95 CAD, Paper.

The Book of Seeds: A Life-Size Guide to Six Hundred Species from Around the World. Edited by Paul Smith. 2018. University of Chicago Press. 656 pages, 55.00 USD, Cloth, 44.00 USD, E-book.

Blossoms and the Genes that Make Them. By Maxine F. Singer. 2018. Oxford University Press. 176 pages, 22.95 CAD, Cloth. Also available as an E-book.

Sunflowers. By Stephen A. Harris. 2018. University of Chicago Press. 256 pages, 27.00 USD, Cloth.

Palm. By Fred Gray. 2018. University of Chicago Press. 256 pages, 27.00 USD, Cloth.

The Story of Soy. By Christine M. Du Bois. 2018. Reaktion Books. 216 pages, 40.00 USD, Cloth.

The Ethnobotany of Eden: Rethinking the Jungle Medicine Narrative. By Robert A. Voeks. 2018. University of Chicago Press. 328 pages, 45.00 USD, Cloth or E-book.

Joseph Hooker's Rhododendrons of Sikkim-Himalaya. By Joseph Hooker. Introduction by Virginia Mills and Cam Sharp Jones and an Essay by Ed Ikin. 2018. Royal Botanic Gardens, Kew. 104 pages and 30 colour plates, 35.00 USD, Cloth.

ENTOMOLOGY

The Dynastine Scarab Beetles of the USA and Canada (Coleoptera: Scarabaeidae: Dynastinae). *Bulletin of the University of Nebraska State Museum, Volume 30.* By Brett C. Ratcliffe and Ronald D. Cave. 2017. 298 pages, 40.00 USD.

Insects: Evolutionary Success, Unrivaled Diversity, and World Domination. By David B. Rivers. 2017. Johns Hopkins University Press. 488 pages, 99.95 USD, Cloth or E-book.

Annotated Checklist of the Moths and Butterflies (Lepidoptera) of Canada and Alaska. Pensoft Series Faunistica, Volume 118. By Gregory R. Pohl, Jean-François Landry, B. Christian Schmidt, J. Donald Lafontaine, James T. Troubridge, A. Douglas Macaulay, Erik J. van Nieukerken, Jeremy R. deWaard, Jason J. Dombroskie, John Klymko, Vazrick Nazari, and Ken Stead. 2018. Pensoft Publishers. 580 pages, 78.00 GBP, Cloth. Also available as an open-access E-book.

First in Fly: Drosophila Research and Biological Discovery. By Stephanie Elizabeth Mohr. 2018. Harvard University Press. 270 pages, 35.00 USD, Cloth.

ENVIRONMENT AND CONSERVATION

Making the Most of the Anthropocene: Facing the Future. By Mark Denny. 2017. Johns Hopkins University Press. 224 pages, 24.95 USD, Cloth or E-book.

After Nature: A Politics for the Anthropocene. By Jedediah Purdy. 2018. Harvard University Press. 336 pages, 18.95 USD, Paper.

Fishing Lessons: Artisanal Fisheries and the Future of our Oceans. By Kevin M. Bailey. 2018. University of Chicago Press. 224 pages, 24.00 USD, Cloth, 18.00 USD, E-book.

Extreme Conservation: Life at the Edges of the World. By Joel Berger. 2018. University of Chicago Press. 368 pages, 30.00 USD, Cloth, 18.50 USD, E-book.

Ground Truth: A Guide to Tracking Climate Change at Home. By Mark L. Hines. 2018. University of Chicago Press. 240 pages, 60.00 USD, Cloth, 20.00 USD, Paper, 18.00 USD, E-book.

The Future of Conservation in America: A Chart for Rough Water. By Gary E. Machlis and Jonathan B. Jarvis. Foreword by Terry Tempest Williams. 2018. University of Chicago Press. 112 pages, 40.00 USD, Cloth, 14.00 USD, Paper, 14.00 USD, E-book.

The Marsh Builders. The Fight for Clean Water, Wetlands, and Wildlife. By Sharon Levy. 2018. Oxford University Press. 248 pages, 39.95 CAD, Cloth. Also available as an E-book.

Climate Garden 2085: Handbook for a Public Experiment. Edited by Manuela Dahinden and Juanita Schläpfer-Miller.

Photography by Nina Mann. 2018. Park Books. 98 pages and 76 colour plates, 29.00 USD, Cloth.

Effective Ecological Monitoring, Second Edition. By David Lindenmayer and Gene Likens. 2018. CSIRO Publishing. 224 pages, 49.95 AUD, Paper.

The Wasting of Borneo: Dispatches from a Vanishing World. By Alex Shoumatoff. 2018. Beacon Press. 224 pages, 18.00 USD, Paper.

ORNITHOLOGY

***The Birds of Vancouver Island's West Coast.** By Adrian Dorst. 2018. UBC Press, On Point Press. 544 pages and 140 black and white photos/maps, 39.95 CAD, Cloth.

Ecology and Conservation of Forest Birds. Edited by Grzegorz Mikusiński, Jean-Michel Roberge, and Robert Fuller. 2018. Cambridge University Press. 566 pages, 114.95 CAD, Cloth, 56.95 CAD, Paper, 40.00 USD, E-book.

Birds in Their Habitats: Journeys with a Naturalist. By Ian Fraser. 2018. CSIRO Publishing. 240 pages, 39.95 AUD, Paper. Also available as an E-book.

Moral Entanglements: Conserving Birds in Britain and Germany. By Stefan Bargheer. 2018. University of Chicago Press. 336 pages, 105.00 USD, Cloth, 35.00 USD, Paper, 35.00 USD, E-book.

Owl. By Desmond Morris. 2018. Reaktion Books. 216 pages, 16.00 USD, Paper.

Penguins in the Desert. By Eric Wagner. 2018. Oregon State University Press. 256 pages, 22.95 CAD, Paper.

***Seabird Colonies of British Columbia: A Century of Changes. Wildlife Afield, Volume 13, Numbers 1 & 2, Pages 1–298, January – December 2016.** By Michael S. Rodway, R. Wayne Campbell, and Moira J. F. Lemon. 2017. Biodiversity Centre for Wildlife Studies. 298 pages, 40.00 CAD, Paper.

***The Birds at My Table. Why We Feed Wild Birds and Why It Matters.** By Darryl Jones. 2018. Cornwell University Press, Comstock Publishing Associates. 352 pages, 19.95 USD, Paper.

***Best Places to Bird in the Prairies.** By John Acorn, Alan Smith, and Nicola Koper. Foreword by Candace Savage. Series edited by Richard Cannings and Russell Cannings. 2018. Greystone Books. 280 pages, 24.95 CAD, Paper.

Birds of Prey of the East. By Brian K. Wheeler. 2018. Princeton University Press. 304 pages, 27.95 USD, Paper Flexibound.

Birds of Prey of the West. By Brian K. Wheeler. 2018. Princeton University Press. 360 pages, 27.95 USD, Paper Flexibound.

Urban Raptors: Ecology and Conservation of Birds of Prey in Cities. Edited by Clint W. Boal and Cheryl R. Dykstra. 2018. Island Press. 232 pages, 80.00 USD, Cloth, 40.00 USD, Paper or E-book.

Common & Spotted Sandpipers. By Phil Holland. 2018. Whittles Publishing. 176 pages, 18.99 GBP, Paper.

The Ascent of Birds: How Modern Science is Revealing their Story. By John Reilly. 2018. Pelagic Publishing. 340 pages, 44.84 CAD / 24.99 GBP, Cloth.

Listening in the Field: Recording and the Science of Bird-song. By Joeri Bruyninckx. 2018. MIT Press. 256 pages, 34.00 USD, Cloth.

A Shadow Above: The Fall and Rise of the Raven. By Joe Shute. 2018. Bloomsbury. 272 pages, 24.00 USD, Cloth.

ZOOLOGY

Skeletons: The Frame of Life. By Jan Zalasiewicz and Mark Williams. 2018. Oxford University Press. 320 pages, 24.95 CAD, Cloth. Also available as an E-book.

Animal Locomotion, Second Edition. By Andrew Biewener and Sheila Patek. 2018. Oxford University Press. 256 pages, 95.00 CAD, Cloth, 45.95 CAD, Paper. Also available as an E-book.

The Natural History of the Crustacea: Life Histories, Volume 5. Edited by Martin Thiel and Gary A. Wellborn. 2018. Oxford University Press. 456 pages, 175.00 CAD, Cloth. Also available as an E-book.

Cephalopod Behaviour, Second Edition. By Roger T. Hanlon and John B. Messenger. 2018. Cambridge University Press. 232 pages, 177.95 CAD, Cloth, 74.95 CAD, Paper. Also available as an E-book.

The Curious Life of Krill: A Conservation Story from the Bottom of the World. By Stephen Nicol. 2018. Island Press. 190 pages, 30.00 USD, Cloth or E-book.

The New Chimpanzee: A Twenty-First-Century Portrait of Our Closest Kin. By Craig Stanford. 2018. Harvard University Press. 260 pages, 35.00 USD, Cloth.

When the Caribou Do Not Come: Indigenous Knowledge and Adaptive Management in the Western Arctic. Edited by Brenda L. Parlee and Ken J. Caine. 2018. UBC Press. 288 pages, 75.00 CAD, Cloth.

Mountain Lions of the Black Hills: History and Ecology. By Jonathan A. Jenks. 2018. Johns Hopkins University Press. 160 pages, 75.00 USD, Cloth or E-book.

The Rise of Marine Mammals: 50 Million Years of Evolution. By Annalisa Berta. 2017. Johns Hopkins University Press. 216 pages, 75.00 USD, Cloth or E-book.

Reproduction in Mammals: The Female Perspective. By Virginia Hayssen and Teri J. Orr. 2017. Johns Hopkins University Press. 368 pages, 69.95 USD, Cloth or E-book.

Lagomorphs: Pikas, Rabbits, and Hares of the World. Edited by Andrew T. Smith, Charlotte H. Johnston, Paulo C. Alves, and Klaus Hackländer. 2018. Johns Hopkins University Press. 280 pages, 89.95 USD, Cloth.

Stream Fish Community Dynamics: A Critical Synthesis. By William J. Matthews and Edie Marsh-Matthews. 2017.

Johns Hopkins University Press. 360 pages, 64.95 USD, Cloth or E-book.

North Atlantic Right Whales: From Hunted Leviathan to Conservation Icon. By David W. Laist. 2017. Johns Hopkins University Press. 464 pages, 44.95 USD, Cloth or E-book.

The Snake and the Salamander: Reptiles and Amphibians from Maine to Virginia. By Alvin R. Breisch. Illustrations by Matt Patterson. 2017. Johns Hopkins University Press. 232 pages, 49.95 USD, Cloth or E-book.

Return of the Sea Otter: The Story of the Animal That Evaded Extinction on the Pacific Coast. By Todd McLeish. 2018. Sasquatch Books. 264 pages, 19.95 USD, Paper, 9.99 USD, E-book.

Hair and Fur Atlas of Central European Mammals. By Mária Tóth. 2017. Pars Ltd., Nagykovácsi, Hungary. 307 pages, 38 EUR, Cloth.

Bats: In a World of Echoes. By Johan Eklöf and Jens Rydell. 2018. Springer International Publishing. 176 pages, 49.99 USD, Cloth, 39.99 USD, E-book.

Bat. By Tessa Laird. 2018. Reaktion Books. 224 pages, 19.95 USD, Paper.

American Snakes. By Sean P. Graham. Foreword by Rick Shine. 2018. Johns Hopkins University Press. 293 pages, 29.95 USD, Cloth or E-book.

OTHER

***The Subjugation of Canadian Wildlife: Failures of Principle and Policy.** By Max Foran. 2018. McGill-Queen's University Press. 440 pages, 39.95 CAD, Cloth.

The Overstory: A Novel. By Richard Powers. 2018. W.W. Norton. 512 pages, 27.95 USD, Cloth.

The Death and Life of the Great Lakes. By Dan Egan. 2018. W.W. Norton. 384 pages, 17.95 USD, Paper.

Becoming a Wildlife Professional. Edited by Scott E. Henke and Paul R. Krausman. 2017. Johns Hopkins University Press. 232 pages, 85.00 USD, Cloth or E-book.

House of Lost Worlds: Dinosaurs, Dynasties, and the Story of Life on Earth. By Richard Conniff. 2017. Yale University Press. 352 pages, 25.00 USD, Paper.

Discoveries in the Garden. By James Nardi. 2018. University of Chicago Press. 288 pages, 75.00 USD, Cloth, 25.00 USD, Paper, 18.00 USD, E-book.

Land Bridges: Ancient Environments, Plant Migrations, and New World Connections. By Alan Graham. 2018. University of Chicago Press. 288 pages, 150.00 USD, Cloth, 50.00 USD, Paper or E-book.

Unnatural Selection. By Katrina van Grouw. 2018. Princeton University Press. 304 pages and 400 black and white illustrations, 45.00 USD, Cloth.

The Evolution of Beauty: How Darwin's Forgotten Theory of Mate Choice Shapes the Animal World – and Us. By Richard O. Prum. 2017. Doubleday. 448 pages, 30.00 USD/40.00 CAD, Cloth.

A Taste for the Beautiful: The Evolution of Attraction. By Michael J. Ryan. 2018. Princeton University Press. 208 pages, 27.95 USD/22.95 GBP, Cloth.

Pasta for Nightingales: A 17th-Century Handbook of Bird-Care and Folklore. By Cassiano dal Pozzo. Illustrations by Cassiano dal Pozzo. Translated by Kate Clayton. Foreword by Helen Macdonald. 2018. Yale University Press. 144 pages and 150 colour illustrations, 22.50 USD, Cloth.

Darwin's Fossils: Discoveries that Shaped the Theory of Evolution. By Adrian Lister. 2018. CSIRO Publishing. 224 pages, 29.95 AUD, Paper.

Biology of Sex. By Alex Mills. 2018. University of Toronto Press. 368 pages and 120 illustrations, 165.00 CAD, Cloth, 74.95 CAD, Paper, 59.95 CAD, E-book.

Phoenix Zones: Where Strength is Born and Resilience Lives. By Hope Ferdowsian. 2018. University of Chicago Press. 224 pages, 22.50 USD, Cloth, 18.00 USD, E-book.

The Scientific Journal: Authorship and the Politics of Knowledge in the Nineteenth Century. By Alex Csiszar. 2018. University of Chicago Press. 368 pages, 45.00 USD, Cloth, 45.00 USD, E-book.

This Land Is Your Land: The Story of Field Biology in America. By Michael J. Lanoo. 2018. University of Chicago Press. 304 pages, 90.00 USD, Cloth, 30.00 USD, Paper, 30.00 USD, E-book.

Rare and Wonderful: Treasures from the Oxford University Museum of Natural History. By Kate Diston and Zoë Simmons. 2018. Bodleian Library, University of Oxford. 224 pages, 35.00 USD, Cloth.

The Rhinoceros and the Megatherium: An Essay in Natural History. By Juan Pimentel. Translated by Peter Mason. 2017. Harvard University Press. 368 pages, 29.95 USD, Cloth.

News and Comment

Upcoming Meetings and Workshops

Association of Field Ornithologists and Wilson Ornithological Society Joint Meeting

The 2018 joint meeting of the Association of Field Ornithologists and the Wilson Ornithological Society to be held 7–9 June 2018 at the Chattanooga Convention Center, Chattanooga, Tennessee. Registration is currently open. More

information is available at <http://www.event.com/events/2018-afo-wos-meeting/event-summary-9bb245ce39b4492280fa6c65382e9f83.aspx>.

Entomological Society of America, Pacific Branch Meeting

The 102nd annual meeting of the Pacific Branch of the Entomological Society of America to be held 10–13 June 2018 at the Atlantis Casino Resort Spa, Reno, Nevada. Registration

is currently open. More information is available at <https://www.entsoc.org/pacific/2018-branch-meeting>.

International Association of Great Lakes Research Conference

The 61st annual International Association of Great Lakes Research Conference, hosted by the University of Toronto: Scarborough, to be held 18–22 June 2018 in Scarborough, Ontario. The theme of the conference is: 'Great Science for

Tomorrow's Solutions'. Registration is currently open. More information is available at <http://iaglr.org/index.php/iaglr2018>.

Eastern Bird Banding Association Annual Meeting

The annual meeting of the Eastern Bird Banding Association to be held 22–24 June 2018 at the Schoodic Institute at Acadia National Park, Schoodic Peninsula, Maine. Regis-

tration is currently open. More information is available at <http://www.easternbirdbanding.org/2018-cbba-meeting>.

American Society of Mammalogists Annual Meeting

The 98th annual meeting of the American Society of Mammalogists to be held 25–29 June 2018 at Kansas State Univer-

sity, Manhattan, Kansas. Registration is currently open. More information is available at <http://www.mammalmeetings.org>.

Canadian Society for Ecology & Evolution Meeting

The Canadian Society for Ecology & Evolution Meeting to be held 18–21 July 2018 at the University of Guelph, Guelph, Ontario. The theme of the conference is: 'Fundamentals in

Ecology and Evolution: Now and into the Future'. Registration is currently open. More information is available at <http://www.csee2018.ca>.

North American Congress for Conservation Biology

The North American Congress for Conservation Biology, hosted by the Wildlife Conservation Society – Canada, University of Toronto, and Society for Conservation Biology's Toronto Chapter, to be held 21–26 July 2018 at the Westin Harbour Castle, Toronto, Ontario. The theme of the congress

is: 'Conservation science, policy, & practice: connecting the urban to the wild'. Registration is currently open. More information is available at <https://scbnorthamerica.org/index.php/naccb2018>.

Botany 2018

Botany 2018 to be held 21–25 July 2018 at the Rochester Civic Center, Rochester, Minnesota. The theme of the meeting is: 'Thriving with diversity'. Registration is currently

open. More information is available at <http://www.botany-conference.org>.

Phycological Society of America and the International Society of Protistologists Joint Meeting

The joint meeting of the Phycological Society of America and the International Society of Protistologists to be held 29 July–2 August 2018 at the University of British Columbia,

Vancouver, British Columbia. Registration is currently open. More information is available at <http://psaisop2018.botany.ubc.ca>.

NEPARC Annual Meeting

The annual meeting of the Northeast Partners in Amphibian and Reptile Conservation (NEPARC) to be held 31 July–2 August 2018 at Hampshire College, Amherst, Massachusetts.

More information is available at <http://northeastpare.org/next-meeting-info>.

Highlights from the Northwest Territories BioBlitzes

To mark Canada's 150th anniversary, BioBlitz Canada 150, a national partnership of nature organizations, brought together the Canadian public with scientists to explore the richness of Canada's biodiversity and to engage our passion to know, celebrate, and conserve our natural heritage. It became known as "Canada's Nature Selfie". The Canadian Wildlife Federation with BioBlitz Canada and other partners in conservation, carried out a series of public BioBlitzes across the nation (Canadian Wildlife Federation 2017). A BioBlitz is an intense period of biological surveying (usually 24 hours) by scientists, naturalists, volunteers, and keen members of the public, in an attempt to record as many living species as possible from a given area. These day-long BioBlitz events are hugely valuable for public outreach, education, and for collecting biological data, including discovery of species not previously known from an area.

The Government of the Northwest Territories organized BioBlitz events in five communities: Inuvik, Tuktoyaktuk, Norman Wells, Fort Simpson, and Yellowknife. New species records for the region are not the only results. Just as important are examples of new information on environmental changes, sharing local knowledge, and helping children to protect and understand nature.

Tuktoyaktuk (28 July 2017, Government Offices, The Point, 69.4507°N, 133.0370°W). The main BioBlitz

event took place on the tip of the peninsula in town, locally called "The Point". This area had hundreds of plants of the spectacular Marsh Felwort (*Lomatogonium rotatum* (L.) Fries). This bright blue-flowered plant is characteristic of cold seashores. The 5 cm long benthic marine isopod *Saduria entomon* (Figure 1) was recorded along the shoreline. Although not the first time it was observed in Tuktoyaktuk—or "Tuk"—(Percy 1983), it may have been the first time this circum-arctic creature had been called by its international (scientific) name. Meadow Slug, *Deroceras laeve*, observed in Tuk and along the shoreline to the west of town is one of the northernmost records in Canada. Among the birds observed in Tuk was the Red-necked Phalarope (*Phalaropus lobatus*; Figure 2), which has experienced major declines in some migratory staging areas. This phalarope has been recently designated as "Special Concern" (COSEWIC 2014a) by the national committee that assesses species at risk in Canada and recommends species for listing under the federal *Species at Risk Act*. Our observations of these birds (and those of others) may help to understand the environmental changes that have caused these declines (and that may influence many other species). We wondered whether American Robins (*Turdus migratorius*) around town may be a new record in Tuk, but in fact these birds were reported over a century ago from groups of trees on the barren lands by Preble (1908).



FIGURE 1. The isopod crustacean, *Saduria entomon* (Chaetiliidae) from the Beaufort Sea, Tuktoyaktuk. 27 July 2017. Photo: P. M. Catling.



FIGURE 2. Red-necked Phalarope (*Phalaropus lobatus*) in a pool on Ocean Drive, Tuktoyaktuk, 26 July 2017. Photo: P. M. Catling.

Local people had the most significant bird observations. We were told that 15 years ago there were very few Bald Eagles (*Haliaeetus leucocephalus*) around Tuk but they have become more common along the Arctic Coast and at the time of the BioBlitz there were 20 observed during our stay in town. We also learned that more Arctic Char (*Salvelinus alpinus*) were being caught and the salmon caught recently had not been caught before. Also, there were several observations of Bowhead (*Balaena mysticetus*) and Beluga (*Delphinapterus leucas*) whales in August (2016 and 2017).

One of the most fascinating biological areas of town included the south pingo. We completed numerous vegetation transects across the pingo that yielded detailed plant lists which will provide a basis for future monitoring related to climate change. Many of the plants on the pingo have a restricted northwestern Arctic distribution, such as Narrow-leaved Saw-wort (*Saussurea*

angustifolia (L.) de Candolle; Figure 3). A true wild orchid, Early Coralroot (*Corallorhiza trifida* Châtelain) was also found in this unusual plant assemblage.

Numerous bumble bees were noted in Tuktoyaktuk including Brown-tailed Bumble Bee (*Bombus mixtus*), Red-tailed Bumble Bee (*Bombus sylvicola*; Figure 4), Yellow-faced Bumble Bee (*Bombus flavitrons*), and Orange-rumped Bumble Bee (*Bombus melanopygus*). These species have been recorded from the Northwest Territories (NWT) before, but noting their abundance in Tuk confirms their distribution in the area and also provides a baseline for future study.

Inuvik (30 July 2017, Aurora Centre to Boot Lake Trail, 68.3558°N, 133.7206°W). The BioBlitz event in Inuvik attracted over 35 people of all ages and followed the main trail part way around Boot Lake (Figure 5). Three hundred plants of the unusual cone-like parasite (on alder) Ground-Cone (*Boschniakia rossica* (Chamisso

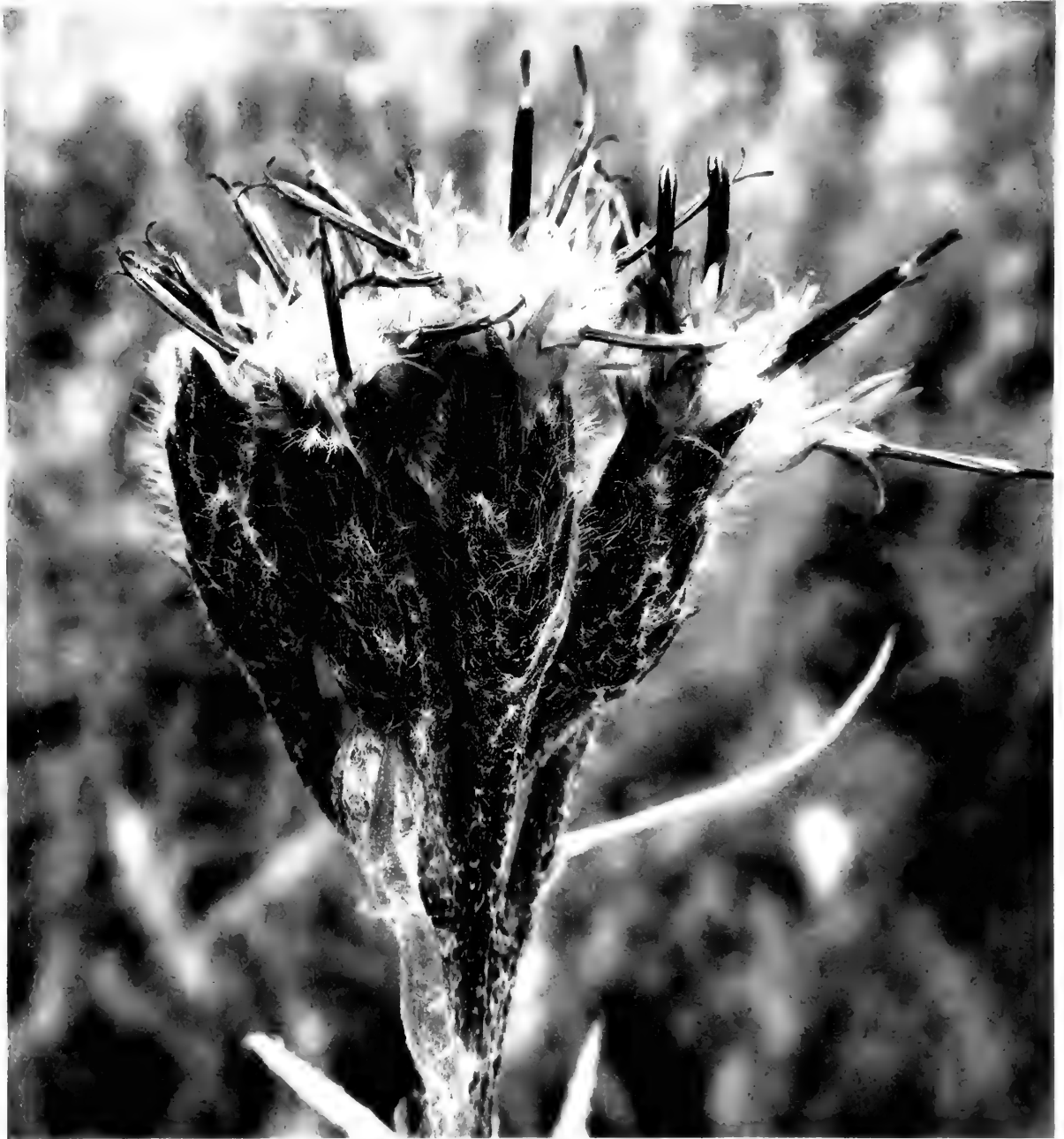


FIGURE 3. Narrow-leaved Saw-wort (*Saussurea angustifolia*) on Tuktoyaktuk's south pingo, 25 July 2017. Photo: P. M. Catling.

so & Schlechtendal) B. Fedtschenko) were found, more than had been observed in one small area before. Along the Mackenzie River were occasional Wood Frogs (*Lithobates sylvaticus*; Figure 6), which are abundant elsewhere in the Mackenzie River delta (for example at Aklavik). The Mackenzie River Delta Wood Frog population is the northernmost population of any frog in Canada.

On the day prior to the Inuvik BioBlitz, both Grizzly Bears (*Ursus arctos*) and Black Bears (*Ursus americanus*) were seen on the Boot Lake trail, but to the relief of some attendees our noisy group of 35 people dis-

couraged an appearance. Everyone wanted to know about what looked like fluorescent orange spray paint on the wild Prickly Roses (*Rosa acicularis* Lindley). To many people's surprise, this was not paint but the spectacular powdery rust fungus, *Phragmidium* (Figure 7). The equally remarkable prickly gall on the rose plants along the trail was caused by a minute chalcidoid gall wasp of the genus *Diplolepis* (possibly *D. bicolor*; Figure 8). An interesting observation was that of Bill Halliday, who identified a Northern Red-backed Vole (*Myodes rutilus*) from bones regurgitated by an owl along the Boot Lake trail.



FIGURE 4. Red-tailed Bumble Bee (*Bombus sylvicola*) at Tuktoyaktuk, 27 July 2017. Photo: J. Heron.



FIGURE 6. Wood Frog (*Lithobates sylvaticus*) from Twin Lakes, Inuvik. The Mackenzie Delta population are the northernmost frogs in Canada. 30 July 2017. Photo: P. M. Catling.

The gravelly open areas along roadsides, around utilidors (utility pipes), and in yards of Inuvik are rich in native vascular plant species, unlike such habitats further south. These included attractive wildflowers such as Alpine Milk-vetch (*Astragalus alpinus* L. var.

alpinus), Marsh Grass-of-Parnassus (*Parnassia palustris* L.), Nodding Locoweed (*Oxytropis deflexa* (Pallas) de Candolle subsp. *foliolosa* (Hooker) Cody), and Raup's Paintbrush (*Castilleja raupii* Pennell). Rich native wildflower habitats of this kind are uncommon



FIGURE 5. Monitoring ducks on Boot Lake during the Inuvik BioBlitz, 30 July 2017. Photo: B. Kostjuk



FIGURE 7. Powdery rust fungus, *Phragmidium*, on wild Prickly Rose (*Rosa acicularis*). Boot Lake Trail, 30 July 2017. Photo: P. M. Catling.



FIGURE 8. Prickly gall on wild Prickly Rose (*Rosa acicularis*) caused by a minute chalcidoid gall wasp of the genus *Diplolepis* (possibly *D. bicolor*). 30 July 2017. Photo: P. M. Catling.

outside of town and may be indicators of a kind of a habitat more frequent in the past and/or localized in the delta region.

Norman Wells (2 August 2017, Historical Centre and the Mackenzie River shoreline, 65.2782°N, 126.8175°W). The biological inventory of Norman Wells included the Mackenzie River shoreline and numerous habitats and trails around town. The diversity and complexity of the Mackenzie River flood shore was a major highlight. The highest water level, indicated by the accumulation of driftwood, was at least 15 m above the water level in early August when we visited (Figure 9). Since the spring, the river had gradually receded leaving land exposed for varying lengths of time and allowed the growth of a diversity of plants at different zones along the shoreline. This led to unusually high plant and animal species diversity. Many of the species present are restricted to this habitat type. Data were collected to evaluate the extent of invasion of the floodshore by the non-native plant, White Sweet-clover (*Melilotus albus* Medikus). This is a fast-growing, fast-spreading, and highly competitive plant and the prospect of losing native plants to this and other non-native competitors before we have discovered all of their values is at least a little worrying. Other plants, such as the rare (in NWT) Alaska Wild Rhubarb (*Aconogonon alaskanum* (W. Wight ex Harshberger) Soják), are potentially important as new Arctic crops. During our visit we found out that the southern limit of this plant (and the site of the population most adapted to a warming climate) was at Tulita.

A gall caused by the Poplar Petiole Gall Aphid, *Pemphigus*, possibly *P. populitransversus* (Figure 10), on Balsam Poplar (*Populus balsamifera* L.) along the Mackenzie was something that we had not seen before. This turned out to be even more interesting because one of the galls contained a parasitic fly larva 1.5 cm long. Aphids that induce closed galls are usually parasitoid free, but parasitoids have been identified from galls in Japan (Takada *et al.* 2010). This may be one of the few cases of parasitism of gall-forming aphids reported in North America.

The Graceful Sedge Grasshopper (*Stethophyma gracile*; Figure 11) recorded at Norman Wells is only the second record for the species in NWT and is 700 km northwest of the previous record from near Kakisa on the south side of Great Slave Lake (Catling 2008). This extension of known range may be a result of a climate that is changing faster than many other regions of the world (Environment and Natural Resources 2016).

Three insect species that have been assessed by the Committee on the Status of Endangered Wildlife in Canada were recorded in Norman Wells: Transverse Lady Beetle (*Coccinella transversoguttata*) and Yellow-banded Bumble Bee (*Bombus terricola*), both species of “Special Concern” (COSEWIC 2016, 2015, respectively), and Gypsy Cuckoo Bumble Bee (*Bombus bohemicus*, Figure 12) an “Endangered” species (COSEWIC 2014b). Numerous other more common bumble bee species were also recorded. These are exciting results, especially Gypsy Cuckoo Bumble Bee, because this bee historically ranged throughout Canada although in the last decade has only been found in northern Canada (COSEWIC 2014b).

Fort Simpson (9 August 2017, Town Golf Course, 61.8586°N, 121.3547°W). This event focussed on macrofungi, lichens, and mosses and involved a group of experts in these groups (see authors and acknowledgements). The community was invited to a walk at the golf course to find examples and later to examine some of the species collected on display tables. Collecting around the Yellowknife area continued from 10 to 12 August. While it was extremely dry during this period, the diversity of macrofungi was surprisingly high (Figure 13). Around 115 collections were made from the Fort Simpson area and 78 from the Yellowknife area. It is estimated that there were 130–150 species found. The icicle fungi *Hericium abietis* (Figure 14), *H. coralloides*, and *H. erinaceus* were spectacular. Most species collected were first reports for NWT. Because *Hebeloma* expert, Dr. Henry Beker, was present, collecting focussed on finding as many *Hebelomas* as possible. None were found at Fort Simpson, but at least three different species were found in Yellowknife. The collections continue to be examined and they will contribute to the very incomplete documentation of these groups in NWT. Only eight species were listed in NWT



FIGURE 9. Mackenzie River flood shore. Within this habitat the Yellow-banded Bumble Bee (*Bombus terricola*) and Transverse Lady Beetle (*Coccinella transversoguttata*), both species of "Special Concern" (COSEWIC 2015, 2016) were observed in abundance. 2 August 2017. Photo: P. M. Catling.



FIGURE 10. A) A gall caused by the Poplar Petiole Gall Aphid, *Pemphigus cf. populitransversus*; B) closer view of gall; and C) fly larva from inside gall. 2 August 2017. Photo: P. M. Catling.

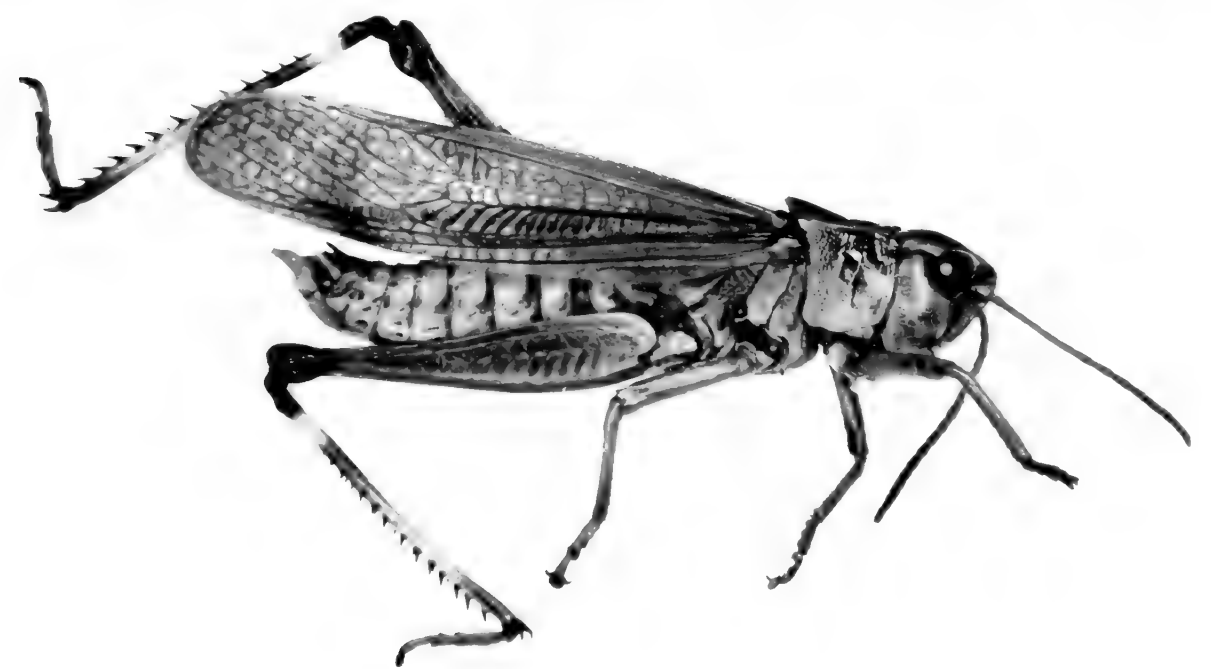


FIGURE 11. The Graceful Sedge Grasshopper (*Stethophyma gracile*) found at Norman Wells was only the second record for the Northwest Territories and a range extension of 700 km northwest. 2 August 2017. Photo: P. M. Catling.

Species 2016–2020 (Working Group on General Status of NWT Species 2016).

Yellowknife (12 August 2017, Prince of Wales Heritage Centre, 62.4575°N, 114.3776°W). In Yellowknife, the outdoor exploratory part of the BioBlitz included the areas near the museum at the west end of Frame Lake and northwest to Niven Lake. Clear-winged Grasshopper (*Camnula pellucida*), common in dry open ground, was a new record for the Yellowknife area. Eighteen species of birds were recorded in two

hours during an early morning bird survey at Niven Lake led by Suzanne Carrière. Earthworms were found at a few places in town and later as far away as the Prelude Lake boat launch. They are not native to NWT but introduced, likely from Europe via southern Canada. Also notable was the Black Meadowhawk dragonfly (*Sympetrum danacae*) which was the most common (68 seen) of eight dragonfly species in the BioBlitz area. It is usually local and uncommon and none have been seen in the previous dragonfly counts in this area, but



FIGURE 12. This Gypsy Cuckoo Bumble Bee (*Bombus bohemicus*) was one of many unusual insects found in Norman Wells. It is a nationally “Endangered Species” (COSEWIC 2014b). Like several other endangered species, its northern populations are the most viable in Canada. 31 July 2017. Photo: C. Sheffield.



FIGURE 13. Mushrooms at Fort Simpson. 8 August 2017. Photo: Linda Davies.



FIGURE 14. Lion's Mane (*Hericium abietis*), an icicle fungus, from near Mackenzie River 1 km north of N'Dulee Ferry Crossing. August 2017. Photo: Sharmin Gamiet.

those counts were in July. Bumble bees were popular with children during the BioBlitz event here and elsewhere (Figure 15). Although the declines in NWT have been less than elsewhere (Working Group on the Status of NWT Species 2016), some bumble bees are rapidly declining in NWT. To assist in monitoring this group of valuable pollinators and environmental indicators, the Government of the Northwest Territories (2017) has produced a free guide.

On the day before the main BioBlitz event at Yellowknife, there was a related event: a tour with members of the non-profit organization, the Yellowknife Association for Community Living. It supports people with disabilities and their families, across their lifetime and aims to help them live meaningful lives and be active in all aspects of community life. The event took place at the Yellowknife River day-use area on the Ingraham Trail. It was well attended; 30 children and youth ages 5 to 15 years joined us for a walk through the woodland trails along the shores of the river. Large insects and spiders were the main attraction, the first observation being a large female orb spider who the group affectionately named “Susan”. There were numerous questions about Susan’s biology, life cycle, number of eggs, lifespan, and hibernation. Interest in the spider was only exceeded by a pair of huge (15 cm wingspan, 5–8 cm long) Lake Darner dragonflies (*Aeshna eremita*), a female and male that were captured by net while holding each other in a mating position (in tandem). Everyone wanted to hold a dragonfly and all were given the opportunity; each participant held the dragonfly carefully by the folded wings and noted the difference between the sexes, their spectacular colours, and their huge eyes. The giant insects were then passed gently to the next person. After each person had their turn at holding each dragonfly, the insects were placed on an open palm and after only brief hesitation, flew away unharmed. No damage after a hand-hold by each of 30 kids! What a wonderful demonstration of care and sensitivity.

BioBlitzes are special events that bring together community members with a common interest in nature and in learning more about the natural world. We were delighted to be part of these events to make new friends in each of these communities, learn from them, and share a respect for nature.

The species observed during the BioBlitz Canada project were recorded using iNaturalist. Species lists can be viewed by following the links below.

Tuktoyaktuk: <http://inaturalist.ca/projects/tuktoyaktuk-bioblitz-2017-de-tuktoyaktuk>.

Inuvik: <http://inaturalist.ca/projects/inuvik-bioblitz-2017-de-inuvik>.

Norman Wells: <http://inaturalist.ca/projects/norman-wells-bioblitz-2017-de-norman-wells>.

Yellowknife: <http://inaturalist.ca/projects/yellowknife-bioblitz-2017-de-yellowknife>.



FIGURE 15. Monique Chapman assists in bee identification at the Norman Wells BioBlitz, 2 August 2017. Photo: B. Kostiuk.

Acknowledgements

Numerous people were involved in documenting species and coordinating access and logistics. In particular, Suzanne Carrière, Wildlife Biologist (Biodiversity), Government of the Northwest Territories (GNWT), played a key role. Stephanie Yuill, also of GNWT, played a major role in organizing the Yellowknife BioBlitz and Julie Ross, Centre Director, made the outstanding facilities of Yellowknife's Prince of Wales Heritage Centre available. Great help was also provided by: Sister Fay Tromblay and Roy and Julia Cockney of Tuktoyaktuk; Catarina Owen, Annika Trimble, and Erika Hille of the Aurora Research Institute in Inuvik; Wesley Hodgson, Richard and Napache Popko, and Dave Wilderspin of Norman Wells; and Henry Beker, Linda Davies, Diane Haughland, Toby Spribille, Karen Golinski, Tim Wheeler, and Spencer Goyette at the Fort Simpson and Yellowknife BioBlitzes.

Literature Cited

Aiken, S. G., M. J. Dallwitz, L. L. Consaul, C. L. McJannet, R. L. Boles, G. W. Argus, J. M. Gillett, P. J. Scott, R. Elven, M. C. LeBlanc, L. J. Gillespie, A. K. Brysting, H. Solstad, and J. G. Harris. 2007. Flora of the Canadian Arctic Archipelago: descriptions, illustrations, identification, and information retrieval. NRC Research Press, National Research Council of Canada, Ottawa, Ontario, Canada. Accessed 27 December 2017. <http://nature.ca/aafflora> data.

Canadian Wildlife Federation. 2017. BioBlitz Canada 150 events. Accessed 27 December 2017.

<http://bioblitzcanada.ca>.

<http://bioblitzcanada.ca/about/bbc.aspx>.

http://bioblitzcanada.ca/events_map.aspx.

http://bioblitzcanada.ca/events_community-northwest-territories.aspx.

http://bioblitzcanada.ca/project_bioblitz-in-a-box.aspx#toc_2-10-check-list-of-items-to-include-in-final-report-to-the-canadian-wildlife-federation-.

Catling, P. M. 2008. Grasshoppers and related insects of Northwest Territories and adjacent regions. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, Northwest Territories, Canada.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2014a. COSEWIC assessment and status report on the Red-necked Phalarope, *Phalaropus lobatus*, in Canada. COSEWIC, Ottawa, Ontario, Canada. Accessed 18 May 2018. <http://sararegistry.gc.ca/virtual-sara/files/cosewic-sr-Red-neckedPhalarope-2014-e.pdf>.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2014b. COSEWIC assessment and status report on the Gypsy Cuckoo Bumble Bee *Bombus bohemicus* in Canada. COSEWIC, Ottawa, Ontario, Canada. Accessed 17 May 2018. <http://sararegistry.gc.ca/virtual-sara/files/cosewic-sr-GypsyCuckooBumbleBee-2014-e.pdf>.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2015. COSEWIC assessment and status report on the Yellow-banded Bumble Bee *Bombus*

- terricola* in Canada. COSEWIC, Ottawa, Ontario, Canada. Accessed 17 May 2018. http://sararegistry.gc.ca/virtual_sara/files/cosewic/sr_Yellow-banded_BumbleBee_2015_e.pdf.
- COSEWIC (Committee on the Status of Endangered Wildlife in Canada).** 2016. COSEWIC assessment and status report on the Transverse Lady Beetle *Coccinella transversoguttata* in Canada. COSEWIC, Ottawa, Ontario, Canada. Accessed 17 May 2018. http://sararegistry.gc.ca/virtual_sara/files/cosewic/sr_Transverse_Lady_Beetle_2016_e.pdf.
- Environment and Natural Resources.** 2016. NWT state of the environment report – highlights 2016. Department of Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, Northwest Territories, Canada. Accessed 27 December 2017. http://www.enr.gov.nt.ca/sites/enr/files/state_of_environment_highlights_2016.pdf.
- Government of the Northwest Territories.** 2017. A Field Guide to the Bumble Bees of the Northwest Territories. Government of the Northwest Territories, Yellowknife, Northwest Territories, Canada.
- Takada, H., K. Kamijo, and H. Torikura.** 2010. An aphidiine parasitoid *Monoctonia vesicarii* (Hymenoptera: Braconidae) and three chalcidoid hyperparasitoids of *Pemphigus matsumurai* (Homoptera: Aphididae) forming leaf galls on *Populus maximowiczii* in Japan. *Entomological Science* 13: 205–215. <https://doi.org/10.1111/j.1479-8298.2010.00374.x>
- Percy, J. A.** 1983. Distribution of arctic marine isopods of the Mesidotea (= *Saduria*) complex in relation to depth, temperature, and salinity in Southern Beaufort Sea. *Arctic* 36: 341–249.
- Preble, E. A.** 1908. A biological investigation of the Athabasca–Mackenzie region. *North American Fauna* 27. United States Department of Agriculture, Bureau of Biological Survey, Washington, DC, USA.
- Working Group on General Status of NWT Species.** 2016. NWT Species 2016–2020 — general status ranks of wild species in the Northwest Territories. Department of Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, Northwest Territories, Canada. Accessed 27 December 2017. http://www.nwtspeciesatrisk.ca/sites/default/files/nwtspecies_2016_2020_report_final_w_properties.pdf.

PAUL M. CATLING, BRENDA KOSTIUK
Ottawa, ON, Canada

JENNIFER HERON
B.C. Ministry of Environment, Surrey, BC, Canada

RUNEL JIMENEZ
Yellowknife, NWT, Canada

MONIQUE CHAPMAN
Halifax, NS, Canada

SHARMIN GAMIET
Mycology Resources, Abbotsford, BC, Canada

VELMA STERENBERG
Yellowknife, NWT, Canada

Editorial

Celebration of 40 years of COSEWIC and its Close Association with *The Canadian Field-Naturalist*

The year 2017 was celebrated by many as the 150th anniversary of Canada. Some also celebrated the 40th anniversary of the establishment of The Committee on the Status of Endangered Wildlife in Canada (COSEWIC). While the inaugural meeting of COSEWIC occurred in 1977, the first species assessed by COSEWIC occurred in 1978. Federal, provincial, and territorial ministers responsible for wildlife recognized COSEWIC as the source for independent advice on the status of species at risk in Canada in the 1998 *Accord for the Protection of Species at Risk*. When the *Species at Risk Act* (SARA) became law in 2002, COSEWIC was formally established (S. 14) as the body that assesses the risk of extinction or extirpation for all wild flora and fauna within Canada, with the exception of bacteria and viruses, and recommends to the federal government legal listing and protection under SARA.

There has always been a close but informal association between COSEWIC and *The Canadian Field-Naturalist* (CFN). Currently, five Associate Editors of CFN—and yours truly—are, or used to be, members of COSEWIC. Similarly, the numerous reviewers of manuscripts submitted to CFN not only include current and former COSEWIC members but also members of the various Species Specialist Subcommittees, who are tasked with awarding the contracts for and then reviewing the multiple stages of the species status reports, the documents COSEWIC uses to assign status. Many of these status reports, especially those on fishes and marine mammals, were published in CFN from 1984 through 2002 (Halliday 2017). After 2002, COSEWIC status reports have been readily available at sararegistry.gc.ca. While the need to publish COSEWIC status reports in CFN has ended, articles, notes, and thematic collections published in CFN continue to reference COSEWIC status reports or the SARA listings based on COSEWIC status reports. For example, in the four issues of CFN volume 131 for 2017, there are 14 references to COSEWIC status reports or to COSEWIC itself and another six references to species profiles pub-

lished on sararegistry.gc.ca resulting from COSEWIC status reports.

Original descriptions and information on a species' former and current distribution, abundance, behaviour, and interactions with the environment are essential data needed by COSEWIC to assign status. I have long suspected that many articles published in CFN contain these essential data but was surprised to find that there were 62 references to articles published in CFN in the status reports for the 45 wildlife species recently assessed by COSEWIC (see <https://www.canada.ca/en/environment-climate-change/services/committee-status-endangered-wildlife.html> for the results of the April 2018 Wildlife Species Assessment Meeting). More astonishing is that one of the references cited in a COSEWIC status report was for an article (Latchford 1887) published in the first volume of *The Ottawa Naturalist*, a precursor to CFN (Brunton 1986, 2004)—a nice link to help celebrate 40 years of COSEWIC and CFN.

Literature Cited

- Brunton, D. F.** 1986. Additions to the documentation of the publication history of *The Canadian Field-Naturalist* and its predecessors. *Canadian Field-Naturalist* 100: 423–426. Accessed 8 May 2018. <https://www.biodiversitylibrary.org/item/89211#page/441/mode/1up>.
- Brunton, D. F.** 2004. Origins and history of The Ottawa Field-Naturalist's Club. *Canadian Field-Naturalist* 118: 1–38. <https://doi.org/10.22621/cfn.v118i1.879>
- Halliday, W. D.** 2017. Publication trends in *The Canadian Field-Naturalist*, 1980–2015. *Canadian Field-Naturalist* 131: 1–9. <https://doi.org/10.22621/cfn.v131i1.1949>
- Latchford, F. R.** 1887. Report on the Conchological Branch. *Ottawa Naturalist* 1: 107–108. Accessed 8 May 2018. <https://www.biodiversitylibrary.org/item/95417#page/113/mode/1up>.

DWAYNE LEPITZKI

Editor-in-Chief, *The Canadian Field-Naturalist*
Member of COSEWIC

Index to Volume 131

Compiled by William Halliday

- Abies balsamea*, 151
Abundance, 128
Acoustic, Monitoring, 10
Acoustic location system, 10
Agelaius phoeniceus, 312
Airport, Vancouver International, 26
Alces americanus, 215
Alston, J.M., J.E. Millard, J.A. Rick, B.W. Husby, L.A. Mundy. Observations of Notable Parental Behaviours of Northern Spotted Owls (*Strix occidentalis caurina*), 225–227
Alvar, 75
Amphibian decline, 115
Analysis, Meta, 1
Anderson, E.M., 26
Ant, European Fire, 347
Arctic, 23
Ardea Herodias, 369
Aspen, Large-toothed, 128

Balaena mysticetus, 270
Barbe, M., L. Dubois, J. Faubert, M. Lavoie, Y. Bergeron, N.J. Fenton. Range Extensions of 35 Bryophyte Species in the Black Spruce-Feather Moss Forest of Western Quebec, Canada, 258–269
Baril, L.M., D.B. Haines, L.E. Walker, D.W. Smith. Autumn Raptor Migration in Yellowstone National Park, 303–311
Baselines, Ecological, 350
Basquill, S., 164
Bay, Constance, 128
Beachcast, 270
Bear, Black, 225
Beaver, American, 215
Beazley, K.F., 32
Behaviour, 23
 Defensive, 235
Extinguished learning, 23
 Foraging, 125
Bell, K.A.H., 37
Bergeron, Y., 258
Bety, J., 203
Bioherms, 46
Bird(s), 303
 Boreal, 55
 Colonial Nesting, 369
 Grassland, 170
BioBlitz, 386
Bison, 221
Bison bison, 221
Blackbird, Red-winged, 312
Blaney, S., 164
Blouin-Demers, G., 228
Boreal, 151
Boudreau, M.R., 344
Bradbeer, D., 26
Breeding, 69, 338, 344
Brigham, R.M., 125
British Columbia
 Bag Harbour, 350
 Brandywine Falls, 144
 Haida Gwaii, 350
 Howe Sound, 46
 Okanagan Valley, 133
 Saanich, 37
 Similkameen Valley, 133
 Vancouver, 26
 Vancouver Island, 120
Brodo, I., 111
Brownsnake
 Dekay's, 235
 Northern, 235
Brunton, D.F., P.M. Catling. Thematic Collection: Alvars in Canada, 75–79
Bryo-geography, 258
Bryoflora, 258
Bryophyta, 246, 258
Bucephala albeola, 338
Bufflehead, 338
Buse, A.J., M.A. Douglas, T.N. Giguere, B.W. Robinson. Adult Snapping Turtle (*Chelydra serpentina*) Feeding on Goldeneye Embryos of Pumpkinseed (*Lepomis gibbosus*) in Defended Nests, 254–257
Butterfly, 63

Calidris pusilla, 203
Callaghan, C. 301
Calliphoridae, 350
Cambarus bartonii bartonii, 335
Canada, 75, 179
Caners, R.T. *Fabronia ciliaris*, a Moss New to Canada from Southeastern Manitoba, 246–251
Canids, 215
Canis
 lupus, 23, 32, 215, 252
 lycaon, 32
Cape
 Graham Moore, 69
 Hay, 69

- Caribou, Woodland, 215
Castor canadensis, 215
 Catling, P.M., 63, 75
 Catling, P.M., B. Kostiuk. Reduced Diversity and Relative Abundance of Terrestrial Snails in a Red Pine Plantation Compared with a Surrounding Red Oak Large-toothed Aspen Woods, 128–132
 Catling, P.M., B. Kostiuk, J. Heron, R. Jimenez, M. Chapman, S. Gamiet, V. Sterenberg. Highlights from the Northwest Territories BioBlitzes, 386–396
 Census, Population, 69
 Chapman, C.J., M.J. Oldham. Reversed Clover, *Trifolium resupinatum* L. (Fabaceae), Confirmed in Canada, 328–330
 Chapman, M., 386
 Change,
 Climate, 55
 Forest, 151
Chelydra serpentina, 254
 Chickadee, Black-capped, 10
Chordeiles minor, 125
 Cipriani, J., 111
 Citizen science, 46, 115
 Clayton, L., G. Dennison. Inexpensive Video Drop-camera for Surveying Sensitive Benthic Habitats: Applications from Glass Sponge (Hexactinellida) Reefs in Howe Sound, British Columbia, 46–54
 Climate change, 55
 Clover
 Persian, 328
 Reversed, 328
 Colony, 369
 Colour, 335
 Conservation, 164, 203, 397
 Cormorant, Double-crested, 347
Corvus, 350
 Cottontail, Nuttall's, 133
 Count, Point, 10
 Crayfish, Appalachian Brook, 335
Cypripedium reginae, 63
Cypseloides niger, 144
 Cyr, M.-A., 69
 Darbyshire, S., S. Blaney, S. Basquill. The First Record for Altai Fescue, *Festuca altaica* (Poaceae), in Nova Scotia, from an Eastern Alpine Site on Cape Breton Island, 164–169
 Dealfish, 325
 Deer, White-tailed, 151
 Defense, Nest, 225
 Dennison, G., 46
 Density
 Ant Nest, 347
 Population, 170, 228
Dermochelys coriacea, 120
 Diet, 19, 26, 215, 225, 254
 Dispersal, 221
 Fungi, 238
 Distribution, 179, 246
 Historical, 32
 Negative binomial, 63
 Disturbance, Human, 215
 Diversity, 128
 Dixon-MacCallum, G.P., K.A.H. Bell, P.T. Gregory. Edge-habitat Use by Northwestern Gartersnakes (*Thamnophis ordinoides*) in Saanich, British Columbia, 37–45
 Dolphin, Pacific White-sided, 120
 Douglas, M.A., 254
 Drop-camera, 46
 Dubois, L., 258
 Eagle, Bald, 369
 Ecology, 203
 Editorial, 397
 Editors' Report for Volume 130 (2016), 301–302
 Ellis-Felege, S.N., C.G. Skaggs, G.A. Knutsen. Increased Bufflehead (*Bucephala albeola*) Breeding Activity in Minnesota, 338–343
 Embryos, Fish, 254
Eozapus, 141
Esox niger, 331
 Estuary, St. Lawrence River, 203
 Evidence, Anecdotal, 32
 Expansion, 338
 Fabaceae, 328
Fabronia
 ciliaris, 246
 pusilla, 246
 Fabroniaceae, 246
Falco columbarius, 344
 Falls, Brandywine, 144
 Faubert, J., 258
 Fenton, 258
 Fescue, Altai, 164
Festuca altaica, 164
 Fir, Balsam, 151
 Fitzsimmons, L.P., 10
 Flight ability, 125
 Floristics, 164
 Flow, Energy, 350
 Flyway, Rocky Mountain, 303
 Food Web, 350
 Foote, J.R., L.P. Fitzsimmons, L.M. Lobert, L.M. Ratcliffe, D.J. Mennill. A Population-level Analysis of Morning Song: Exploring the Implications for Point Counts, 10–18
 Forest
 Ancient, 350
 Boreal, 151, 258

- Found, R., A.A.D. McLaren, A.R. Rodgers, B.R. Patterson. Diet of Grey Wolves (*Canis lupus*) During Calving in a Moose–Caribou System in Northern Ontario, 215–220
- Fox, Red, 19
- Fragmentation, 133
- Fraser, G.S., 347
- Frey, J.K. A Review and the Conservation Implications of Aquatic Behaviour and Drowning in Jumping Mice (Dipodidae: Zapodinae), 141–143
- Frog, Wood, 386
- Fungi
Cave, 238
Cold-tolerant, 238
- Gable, T.D., S.K. Windels, I.C. Rautio. River Otter (*Lontra canadensis*) Killed by Wolves (*Canis lupus*) during Winter in Northern Minnesota, 252–253
- Gamiet, S., 386
- Gartersnake
Common, 228
Northwestern, 37
- Gaston, A.J., M.-A. Cyr, K. O'Donovan. A First Count of Thick-billed Murres (*Uria lomvia*) and Black-legged Kittiwakes (*Rissa tridactyla*) Breeding on Bylot Island, 69–74
- Giguere, T.N., 254
- Grassland, Fescue, 170
- Grebe
Horned, 317
Red-necked, 317
- Gregory, P.T., 37
- Guano, 347
- Gulf, Amundsen, 270
- Gupta, A., K. Rudmik, G.S. Fraser. Evidence for a Negative Effect of Double-crested Cormorants (*Phalacrocorax auritus*) on Invasive European Fire Ants (*Myrmica rubra*), 347–349
- Gynandromorphy, Bicoloured, 335
- Habitats, 228
Sensitive benthic, 46
- Haines, D.B., 303
- Haliaeetus leucocephalus*, 369
- Hall, P., 270
- Hall, P.W., P.M. Catling, P.L. Mosquin, T. Mosquin. European Skipper Butterfly (*Thymelicus lineola*) Associated with Reduced Seed Development of Showy Lady's-slipper Orchid (*Cypripedium reginae*), 63–68
- Halliday, W.D. Publication Trends in *The Canadian Field-Naturalist*, 1980–2015, 1–9
- Hammell, G. Changes to the Population Status of Horned Grebes (*Podiceps auritus*) and Red-necked Grebes (*Podiceps grisegena*) in Southwestern Manitoba, Canada, 317–324
- Hanrahan, C., 111
- Hartzell, S.M. A Bilaterally Partitioned Colour Variant of an Appalachian Brook Crayfish (*Cambarus bartonii bartonii*) from Eastern Pennsylvania, 335–337
- Harwood, L.A., E.V. Lea, S.A. Raverty, P.A. Hall, E. Linn, L. Postma, O. Nielsen. Observations of Beachcast Bowhead Whales (*Balaena mysticetus*) in the Southeastern Beaufort Sea and Amundsen Gulf, 1987–2016, 270–279
- Herbivory, 151
- Herdman, E.J., K.E. Hodges. Habitat Use by Nuttall's Cottontails (*Sylvilagus nuttalli nuttalli*) at their Northern Range Edge (British Columbia, Canada), 133–140
- Heron, Great Blue, 369
- Heron, J., 386
- Hexactinellida, 46
- Hirundo rustica*, 26
- Hodges, K.E., 133
- Holst, M. Marine Mammal and Sea Turtle Sightings During a Survey of the Endeavor Segment of the Juan de Fuca Ridge, British Columbia, 120–124
- Husby, B.W., 225
- Igl, L.D. Sora (*Porzana carolina*) Parasitism of Red-winged Blackbird (*Agelaius phoeniceus*) Nests, 312–315
- Insectivore, Aerial, 26, 144
- Interaction, Predator-prey, 254
- Interference, Pollinator, 63
- Island
Bylot, 69
Cape Breton, 164
Ellesmere, 23
Moresby, 350
- Jimenez, R., 386
- Jung, T.S., N.C. Larter. Observations of Long-distance Post-release Dispersal by Reintroduced Bison (*Bison bison*), 221–224
- Kirschbaum, J., 151
- Kittiwake, Black-legged, 69
- Knutsen, G.A., 338
- Kostiuk, B., 128, 386
- Labrador, Torngat Mountains, 55
- Lady's-slipper, Showy, 63
- Lagenorhynchus obliquidens*, 120
- Lake
Ontario, 331
Simcoe, 369
Superior, 151

- Lamarre, J.-F., 203
 Lamoureux, R.P., M.R. Boudreau, J.L. Seguin. New Breeding Record for Merlin (*Falco columbarius*) in Southwestern Yukon, 344–346
 Larter, N.C., 221
Larus, 350
 Lavoie, M., 258
 Law, A.A., M.E. Threlfall, B.A. Tijman, E.M. Anderson, S. McCann, G. Searing, D. Bradbeer. Diet and Prey Selection of Barn Swallows (*Hirundo rustica*) at Vancouver International Airport, 26–31
 Lea, E.V., 270
 Learned-response, 23
 Learning, 23
 LeGros, D.L. Side to Side Swaying as a Defensive Behaviour in the Dekay's Brownsnake (*Storeria dekayi*), 235–237
 Lepage, D. Minutes of the 138th Annual Business Meeting of the Ottawa Field-Naturalists' Club January 10, 2017, 96–110
 Lepitzki, D. Editorial, 397
 Lepitzki, D., C. Callaghan, A. Martin. Editors' Report for Volume 130 (2016), 301–302
Lepomis gibbosus, 254
 Levesque, P.G., C.A. Rock. Searching for Black Swift (*Cypseloides niger*) Nests in Southern British Columbia, 144–150
 Linn, E., 270
Lithobates sylvaticus, 386
 Liverwort, 258
 Lobert, L.M., 10
Lontra canadensis, 252

 Malloch, D., 238
 Mallon, E., 115
 Mammal, Marine, 120
 Manitoba
 Prairie-potholes, 317
 Southeastern, 246
 Marine mammal, 120
 Marine protected area, Endeavour hydrothermal vent, 120
 Maritime, 32
 Martin, A., 301
 Martin, A.E. Thematic Collection: *The Canadian Field-Naturalist*, Documenting Species New to Canada for Nearly a Century, 179–186
 McAlpine, D.F., 238
 McCann, S., 26
 McGuire, L.P., R.M. Brigham. Common Nighthawks (*Chordeiles minor*) Can Take Off from Water, 125–127
 McLachlan Hamilton, K., 111
 McLaren, A.A.D., 215
 Mech, D.L. Extinguishing a Learned Response in a Free-ranging Gray Wolf (*Canis lupus*), 23–25
 Mennill, D.J., 10
 Merlin, 344
 Meta-analysis, 1
 Migration, 303
 Fall, 203
 Spawning, 350
 Migration timing, 203
 Millard, J.E., 225
 Minnesota, 151
 Great Plains, 338
 Marshall County, 338
 Northern, 252
 Voyageurs National Park, 252
 Minutes of the 138th Annual Business Meeting of the Ottawa Field-Naturalists' Club January 10, 2017, 96–110
Mirounga angustirostris, 120
 Monitoring
 Acoustic, 10
 Browse ecological, 151
 Passive acoustic, 10
 Moore, D.J., 331
 Moose, 215
 Morrison, B.P., D.J. Moore. First Occurrence of a Juvenile Chain Pickerel (*Esox niger*) in Ontario Waters of Lake Ontario, 331–334
 Mosquin, P.L., 63
 Mosquin, T., 63
 Moss, 246, 258
 True, 258
 Mountains, Tornat, 55
 Mouse,
 Deer, 238
 Jumping, 141
 Movement, 133, 221
 Mundy, L.A., 225
 Murre, Thick-billed, 69
 Mycota, Cave, 238
Myrmica rubra, 347

Napaeozapus, 141
 National Monument, Grand Portage, 151
 National Park
 Kluane, 344
 Sirmilik, 69
 Voyageurs, 252
 Yellowstone, 303
 National Wildlife Refuge
 Agassiz, 338
 Great Swamp, 19
 Natural history, 1
 Nesting, 144, 254, 338
 Cavity, 338
 New Brunswick, Sackville, 238
 New Jersey, 19
 Newfoundland, Bay of Exploits, 325
 Nielsen, O., 270

- Nighthawk, Common, 125
 Non-native, 347
 North Dakota, Northern Prairie Wildlife Research Center, 312
 Northwest Territories, 386
 Nova Scotia, Cape Breton Island, 164
Novisuccinea ovalis, 128
 Nunuvut
 Bylot Island, 69
 Ellesmere Island, 23

 O'Donovan, K., 69
 Oak, Northern Red, 128
Odocoileus virginianus, 151
 Oldham, M.J., 328
Oncorhynchus, 350
 Ontario, 115, 328
 Constance Bay, 128
 Kingston, 10
 Lake Ontario, 331
 Northern, 215
 Ottawa Valley, 63
 Rondeau Provincial Park, 235
 Orchid, 63
 Otter, River, 252
 Owl, Northern Spotted, 225

 Parasitism, Brood, 312
 Park, Gatineau, 228
 Partition, Bilateral, 335
 Passive acoustic monitoring, 10
 Patterson, B.R., 215
 Pennsylvania, Stillwater, 335
Peromyscus maniculatus, 238
Phalacrocorax auritus, 347
 Phalarope, Red-necked, 386
Phalaropus lobatus, 386
Phocoenoides dalli, 120
Physeter macrocephalus, 120
 Phytogeography, 246, 258
 Pickerel, Chain, 331
 Pine, Red, 128
Pinus resinosa, 128
 Plantation, Pine, 128
 Plants, Rare, 164
Plethodon cinereus, 115
Podiceps
 auritus, 317
 grisegena, 317
Poecile atricapillus, 10
 Pollination, 63
 Population,
 Peripheral, 133
 Status, 317
Populus grandidentata, 128
 Porpoise, Dall's, 120
Porzana carolina, 312

 Post-release, 221
 Postma, L., 270
 Predation, 215, 254
 Nest, 225, 254, 369
 Prey, 19, 26, 215, 254
 Provinces, Maritime, 32
 Provincial Park
 Rondeau, 235
 Whiteshell, 246
Pseudogymnoascus destructans, 238
 Pumpkinseed, 254
 Purchase, C.F. First Report of Dealfish, *Trachipterus arcticus* (Lampriformes: Trachipteridae), from Canadian Waters, 325–327
 Pylypec, B. Trends in Bird Densities at a Remnant Fescue Grassland in Saskatchewan, 170–178

 Quebec
 Gatineau Park, 228
 Northern, 258
 St. Lawrence River Estuary, 203
Quercus rubra, 128

 Ram-feeding, 254
 Range
 Breeding, 338, 344
 Extension, 258, 325, 328, 331
 Shifts, 55, 179, 258, 325, 328, 331
Rangifer tarandus, 215
 Raptor, 303
 Ratcliffe, L.M., 10
 Rate, Detection, 10
 Rautio, I.C., 252
 Raverty, S.A., 270
 Record, New, 328
 Recording, Remote video, 254
 Reef, Glass sponge, 46
 Regression, Matched-pairs logistic, 37
 Reimchen, T.E. Diverse Ecological Pathways of Salmon Nutrients Through an Intact Marine-terrestrial Interface, 350–368
 Reintroduction, 221
 Reproduction, 369
 Reptiles, 37
 Retamal Diaz, F., G. Blouin-Demers. Northern Snakes Appear Much More Abundant in Old Fields than in Forests, 228–234
 Review, Literature, 1, 32, 75, 141, 179
 Rick, J.A., 225
Rissa tridactyla, 69
 River, North Branch Susquehanna, 335
 Robinson, B.W., 254
 Rock, C.A., 144
 Rodgers, A.R., 215
Rosa acicularis, 386
 Rose, Prickly, 386
 Rudmik, K., 347

- Sagebrush-steppe, 133
 Salamander, Eastern Red-backed, 115
 Sanders, S., J. Kirschbaum. Short-term Change in Forest Metrics at Grand Portage National Monument, Minnesota, 151–163
 Sandpiper, Semipalmated, 203
 Saskatchewan, Saskatoon, 170
Saussurea angustifolia, 386
 Savannah, 128
 Saw-wort, Narrow-leaved, 386
 Seat, 215
 Science, Citizen, 46, 115
 Sea
 Beaufort, 270
 Salish, 46
 Seal, Northern Elephant, 120
 Searing, G., 26
 Seburn, D.C., E. Mallon. Has the Eastern Red-backed Salamander (*Plethodon cinereus*) Declined in Ontario?, 115–119
 Seguin, J.L., 344
 Selection
 Habitat, 228
 Prey, 26, 215
 Serfass, T.L., 19
 Shorebirds, 203
 Shrubification, 55
 Site, Staging, 203
 Skaggs, C.G., 338
 Skipper, European, 63
 Smith, D.W., 303
 Snails,
 Land, 128
 Terrestrial, 128
 Snake, Red-bellied, 228
 Soil, 347
 Song, Dawn, 10
 Sora, 312
 Spawning, 350
 Species
 At risk, 317
 Endangered, 141
 Introduction, 179
 Invasive, 347
 Sphagna, 258
 Sponge, Glass, 46
 Sterenberg, V., 386
Storeria
 dekayi, 235
 occipitomaculata, 228
 Strangling, 270
Strix occidentalis caurina, 225
 Survey,
 Acoustic, 10
 Aerial, 338
 Camera, 19, 46
 Electrofishing, 331
 Pellet, 133, 215
 Quadrat, 128, 151
 Seat, 133, 215
 Seismic, 120
 Transect, 37, 128, 151, 228, 331
 Visual, 37, 115, 120, 128, 144, 170, 203, 228, 303, 317, 338, 350, 369
 Swallow, Barn, 26
 Swaying, 235
 Swift, Black, 144
Sylvilagus nuttalli nuttalli, 133
 Syndrome, White-nose, 238

Thamnophis
 ordinoides, 37
 sirtalis, 228
 Threlfall, M.E., 26
 Thematic collection, 75, 179
 Thermoregulation, Behavioural, 228
 Thompson, B. Effects of Nesting Bald Eagles (*Haliaeetus leucocephalus*) on Behaviour and Reproductive Rates in a Great Blue Heron (*Ardea herodias*) Colony in Ontario, 369–371
Thymelicus lineola, 63
 Tijman, B.A., 26
Trachipterus arcticus, 325
 Trap
 Camera, 19
 Pitfall, 141
 Trends
 Population density, 170
 Publication, 1
 Temporal, 1
 Treeline, 55
Trifolium resupinatum, 328
 Turcotte, Y., J.-F. Lamarre, J. Bety. Annual and Seasonal Variation in Shorebird Abundance in the St. Lawrence Estuary during Fall Migration, 203–214
 Turtle
 Leatherback, 120
 Snapping, 254

Uria lomvia, 69
Ursus, 350
 americanus, 225

 Vanderwolf, K.J., D. Malloch, D.F. McAlpine. Psychrotolerant Microfungi Associated with Deer Mice (*Peromyscus maniculatus*) in a White-nosed Syndrome Positive Bat Hibernaculum in Eastern Canada, 238–245
 Variation, Colour, 335
 Vegetation, Alpine, 164
Vulpes vulpes, 19

Wagnon, C.J., T.L. Serfass. Use of Camera Traps Provides Insight into the Feeding Ecology of Red Foxes (*Vulpes vulpes*), 19–22

Walker, L.E., 303

Web, Food, 350

Whale

 Bowhead, 270

 Sperm, 120

Whitaker, A.N., K.F. Beazley. Evidence for the Historical Occurrence of Wolves (*Canis* spp.) in Nova Scotia, Canada, 32–36

Whitaker, D. Expanded Range Limits of Boreal Birds in the Torngat Mountains of Northern Labrador, 55–62

Wildlife, Urban, 37

Windels, S.K., 252

Wolf

 Eastern, 32

 Gray, 23, 32, 215, 252

Wolves, 32

Woodland, Oak, 128

Wyoming, 303

Yukon, 221

 Kluane National Park, 344

Zapus, 141

Zonitoides arboreus, 128

Zurbrigg, E., I. Brodo, J. Cipriani, C. Hanrahan, K. McLachlan Hamilton. The Ottawa Field-Naturalists’ Club Awards for 2016, presented February 2017, 111–114

Index to Book Reviews

Botany

- Beaudoin, A.B. "Ancient Pathways, Ancestral Knowledge: Ethnobotany and Ecological Wisdom of Indigenous Peoples of Northwestern North America. Volume 1: The History and Practice of Indigenous Plant Knowledge. Volume 2: The Place and Meaning of Plants in Indigenous Cultures and Worldviews" by Nancy J. Turner, 2014, 187–188
- Blain, A. "Curieuses histoires de plantes du Canada. Tome 1: 1000–1670, Tome 2: 1670–1760, Tome 3: 1760–1867" by Alain Asselin, Jacques Cayouette, and Jacques Mathieu, 2014, 2015, 2107, 286–287
- Brunton, D.F. "Exploring the Limestone Barrens of Newfoundland and Labrador" by M. Burzynski, H. Mann, and A. Marceau, 2017, 374
- Brunton, D.F. "Flora of Florida Volume IV (Dicotyledons, Combretaceae through Amaranthaceae" by R.P. Wunderlin, B.F. Hansen, and A.R. Franck, 2017, 375
- Catling, P.M. "Vascular Plants of Alberta, part 1: Ferns, Fern Allies, Gymnosperms, and Monocots" by John G. Packer and A. Joyce Gould, 2017, 80–81
- Iles, M. "Some Useful Wild Plants: A Foraging Guide to Food and Medicine from Nature. Revised Edition" by Dan Jason, 2017, 188–189
- Lamb, E. "Plant Ecology: Origins, Processes, Consequences. Second Edition" by Paul Keddy, 2017, 373–374

Entomology

- Bocking, E. "The Secret Life of Flies" by Erica McAlister, 2017, 287–288
- Cottam, B. "Insects: Their Natural History and Diversity: With a Photographic Guide to Insects of Eastern North America. Second Edition, Revised and Updated" by Stephen A. Marshall, 2017, 288–289

Ornithology

- John, R. "Raptors: The Curious Nature of Diurnal Birds of Prey" by Keith Bildstein, 2017, 289–290
- John, R. "The Australian Bird Guide" by Peter Menckhorst, Danny Rogers, Rohan Clarke, Jeff Davies, Peter Marsack, and Kim Franklin, 2017, 290–291

Other

- Armstrong, T. "Coexistence: The Ecology and Evolution of Tropical Biodiversity" by Jan Sapp, 2016, 295–296
- Bocking, E. "The Carbon Code: How You Can Become a Climate Change Hero" by Brett Favaro, 2017, 85–86
- Brooks, R. "The Book that Changed America. How Darwin's Theory of Evolution Ignited a Nation" by Randall Fuller, 2017, 194–195
- Brownstein, D. "The Sustainability Dilemma: Essays on British Columbia Forest and Environmental History" by Robert Griffin and Richard A. Rajala, 2017, 197–199
- Burke, T. "The Eye of the Sandpiper: Stories from the Living World" by Brandon Keim, 2017, 296–297
- Cottam, B. "Protecting the Planet: Environmental Champions from Conservation to Climate Change" by Budd Titlow and Mariah Tinger, 2016, 86–87
- Cottam, B. "Alexander Wilson: Enlightened Naturalist. *Aperçus: Histories Texts Cultures Series*" by Edward H. Burt, Jr., 2016, 87–89
- Cottam, B. New Titles, 90–93, 199–201, 297–300, 382–384
- Cottam, B. "Pilgrims of the Air: The Passing of the Passenger Pigeons" by John Wilson Foster, 2014/2017, 380–381
- Gaston, T. "Ice Blink: Navigating Northern Environmental History" by Stephen Bocking and Brad Martin, 2017, 86
- Gaston, T. "Mourning Nature: Hope at the Heart of Ecological Loss and Grief" by Ashlee Cunsolo and Karen Landman, 2017, 192
- Gaston, T. "Rise of the Necrofauna: The Science, Ethics and Risks of De-Extinction" by Britt Wray, 2017, 293
- Halliday, W.D. "The Arctic Guide: Wildlife of the Far North" by Sharon Chester, 2016, 196
- Smith, C.M. "Best Places to Bird in British Columbia" by Russell Cannings and Richard Cannings, 2017, 85
- Smith, C.M. "This River Beneath the Sky: A Year on the Platte" by Doreen Pfof, 2017, 193
- Smith, C.M. "The Magnificent Nahanni: The Struggle to Protect a Wild Place" by Gordon Nelson, 2017, 293–294
- Smith, T. "Blooms. An Illustrated History of the Ornamental Gardens at Ottawa's Central Experimental Farm" by Richard Hinchcliff, 2016, 84
- Tegler, B. "Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming" by Paul Hawken, 2016, 197

Poetry

Citron, M. "Welcome to the Anthropocene" by Alice Major, 2018, 372–373

Zoology

Armstrong, T. "Encyclopedia of Whales, Dolphins and Porpoises" by Erich Hoyt, 2017, 377–379

Burke, T. "Flock Together: A Love Affair with Extinct Birds" by B.J. Hollars, 2017, 190–191

Halliday, W.D. "Marine Fishes of Arctic Canada" by Brian W. Coad and James D. Reist, 2017, 377

Lauff, R. "Fireflies, Glow-worms, and Lightning Bugs: Identification and Natural History of the Fireflies of the Eastern and Central United States and Canada" by Lynn Frierson Faust, 2017, 191–192

Lauff, R. "Great White Shark: Myth and Reality" by Alexandrine Civard-Racinais, 2017, 379

Lauff, R. "The Skeleton Revealed: An Illustrated Tour of the Vertebrates" by Steve Huskey, 2017, 380

Lennox, R.J. "Ecology of Salmonids in Estuaries around the World: Adaptations, Habitats, and Conservation" by Colin D. Levings, 2016, 81–82

Smith, C.M. "Birdmania: A Remarkable Passion for Birds" by Bernd Brunner, 2017, 189–190

Way, J. "Heart of a Lion: A Lone Cat's Walk Across America" by William Stolzenburg, 2016, 82–84

Way, J. "Wolves of the Yukon" by Bob Hayes, 2010, 291–293

Way, J. "The Wolf: A True Story of Survival and Obsession in the West" by Nate Blakeslee, 2017, 375–376

Book Reviews

POETRY: Welcome to the Anthropocene	372
BOTANY: Plant Ecology: Origins, Processes, Consequences, Second Edition — Exploring the Limestone Barrens of Newfoundland and Labrador — Flora of Florida Volume IV (Dicotyledons, Combretaceae through Amaranthaceae)	373
ZOOLOGY	
The Wolf: A True Story of Survival and Obsession in the West — Marine Fishes of Arctic Canada — Encyclopedia of Whales, Dolphins and Porpoises — Great White Shark: Myth and Reality — The Skeleton Revealed: An Illustrated Tour of the Vertebrates	375
OTHER: Pilgrims of the Air: The Passing of the Passenger Pigeons	380
NEW TITLES	382

News and Comment

Upcoming Meetings and Workshops

Association of Field Ornithologists and Wilson Ornithological Society Joint Meeting — Entomological Society of America, Pacific Branch Meeting — International Association of Great Lakes Research Conference — Eastern Bird Banding Association Annual Meeting — American Society of Mammalogists Annual Meeting — Canadian Society for Ecology & Evolution Meeting — North American Congress for Conservation Biology — Botany 2018 — Phycological Society of America and the International Society of Protistologists Joint Meeting — NEPARC Annual Meeting	385
--	-----

Highlights from the Northwest Territories BioBlitzes	386
--	-----

Editorial

Celebration of 40 years of COSEWIC and its Close Association with <i>The Canadian Field-Naturalist</i>	397
--	-----

Index to <i>The Canadian Field-Naturalist</i> Volume 131	BY WILLIAM HALLIDAY	398
--	---------------------	-----

Mailing date of the previous issue 131(3): 11 April 2018

Autumn raptor migration in Yellowstone National Park, 2011–2015 LISA M. BARIL, DAVID B. HAINES, LAUREN E. WALKER, and DOUGLAS W. SMITH	303
Sora (<i>Porzana carolina</i>) parasitism of Red-winged Blackbird (<i>Agelaius phoeniceus</i>) nests LAWRENCE D. IGL	312
Changes to the population status of Horned Grebes (<i>Podiceps auritus</i>) and Red-necked Grebes (<i>Podiceps grisegena</i>) in southwestern Manitoba, Canada GORD HAMMELL	317
First report of Dealfish, <i>Trachipterus arcticus</i> (Lampriformes: Trachipteridae), from Canadian waters CRAIG F. PURCHASE	325
Reversed Clover, <i>Trifolium resupinatum</i> L. (Fabaceae), confirmed in Canada COLIN J. CHAPMAN and MICHAEL J. OLDHAM	328
First occurrence of a juvenile Chain Pickerel (<i>Esox niger</i>) in Ontario waters of Lake Ontario BRIAN P. MORRISON and DANIEL J. MOORE	331
A bilaterally partitioned colour variant of an Appalachian Brook Crayfish (<i>Cambarus bartonii bartonii</i>) from eastern Pennsylvania SEAN M. HARTZELL	335
Increased Bufflehead (<i>Bucephala albeola</i>) breeding activity in Minnesota SUSAN N. ELLIS-FELEGÉ, CASSANDRA G. SKAGGS, and GREGORY A. KNUTSEN	338
New breeding record for Merlin (<i>Falco columbarius</i>) in southwestern Yukon RYAN P. LAMOUREUX, MELANIE R. BOUDREAU, and JACOB L. SEGUIN	344
Evidence for a negative effect of Double-crested Cormorants (<i>Phalacrocorax auritus</i>) on invasive European Fire Ants (<i>Myrmica rubra</i>) ADITI GUPTA, KRISTI RUDMIK, and GAIL S. FRASER	347
Diverse ecological pathways of salmon nutrients through an intact marine-terrestrial interface THOMAS E. REIMCHEN	350
Effects of nesting Bald Eagles (<i>Haliaeetus leucocephalus</i>) on behaviour and reproductive rates in a Great Blue Heron (<i>Ardea herodias</i>) colony in Ontario BILL THOMPSON	369

(continued on inside back cover)

ISSN 0008-3550

